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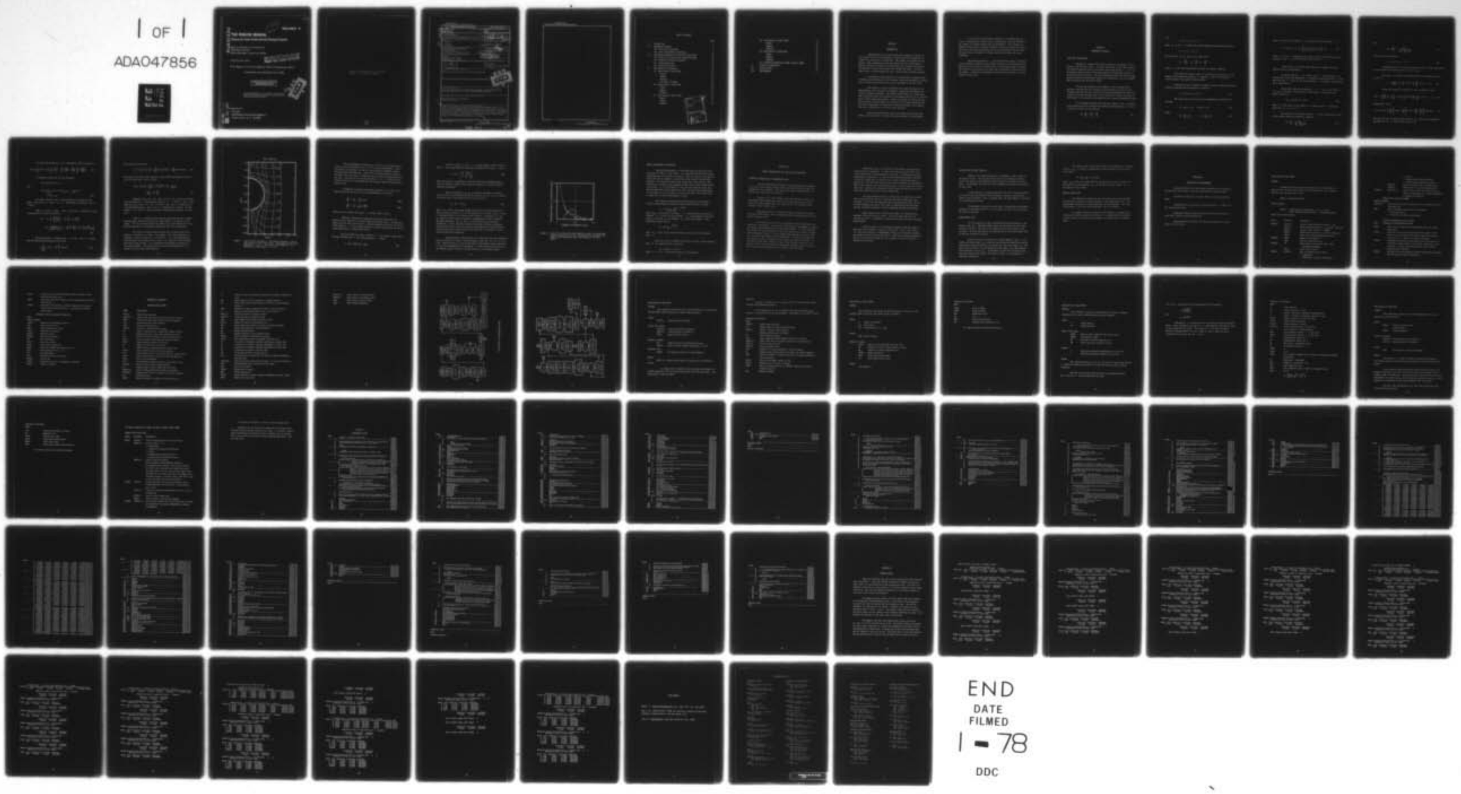

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THE ROSCOE MANUAL

Volume 8—Flow Fields Around Rising Fireballs

Mission Research Corporation
735 State Street
Santa Barbara, California 93101

31 December 1974

Final Report for Period 2 March 1974—31 December 1974

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A model is presented here to give the detailed position-time history of a parcel of fluid flowing around a rising spherical fireball vortex. The model is based on the assumption of steady incompressible, irrotational flow around the spherical vortex. The model has been coded for use in large systems type codes. The technique used is based on interpolation from a solution table. Included is the Fortran coding and typical output.

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SECTION 1

INTRODUCTION

Hydrodynamics has in recent years given impressive results in the solution of flow field problems by making simplified assumptions of steady flow relative to a moving body. This aspect has appeared in many physics codes attempting to solve the problem of the rising fireball. However, because of computing considerations, flow fields have generally been ignored in large system codes such as RANC and others. This has meant errors in energy deposition and a resulting ghost fireball problem.

A solution to these problems for system codes is presented here. By modeling the hydrodynamic flow using the simplified assumption of steady flow, the detailed particle motion can be specified in the flow field.

This model is a result of advances that have been made in the understanding of fluid particle movement by studying the deformation of "drift" of material surfaces. Sir Charles Darwin (1953) has drawn important conclusions about the movements of individual particles in irrotational flow of fluid around hard objects. Darwin considered an infinitely thin plane of fluid at right angles to the motion of the sphere and asked what the final displacement of the plane was after the passage of the sphere. This final displacement is the total drift function.

Darwin's method has been used to calculate the position-time history of the particles of fluid as they move around a rising fireball.

To solve the rising fireball problem, it is assumed that the fluid is incompressible and the flow is irrotational, that the fireball at any instant is a perfect sphere with no entrainment. This reduces the problem of finding the velocities anywhere in the field outside the fireball to one of taking the gradient of a velocity-potential for an incompressible fluid, the motion is steady; thus the fluid does not cross steamlines.

The velocity-potential ϕ can be found from Laplace's equation with the boundary condition of no radial velocities at the surface of the sphere and zero velocity at infinity for a fluid moving around the sphere. The velocities and positions are found for a coordinate system fixed with the sphere. A Galilean transformation then gives the position in a frame fixed with the fluid.

SECTION 2

MATHEMATICAL METHOD

FLOW FIELD CALCULATION

Consider an infinite thin plane of fluid at right angles to the motion of the fireball vortex. It can be asked, what is the final shape of the marked fluid plane after the fireball has passed through it. It is to be expected that the part of the plane nearest the spheroidal fireball is moved the greatest distance. The fluid contained between the initial plane position and its final position equals the "hydrodynamic mass" or "virtual" mass associated with the body's motion.

To solve the problem of what happens to the displaced fluid particles requires that the streamlines be determined and also the time at which each fluid particle reaches a given point measured from some fixed reference time for the particles—in this case when it passes the plane at right angles to the center of the spheroid had it been an undisturbed region.

In a coordinate system fixed with the fireball, with z parallel to the direction of the flow and the reference point defined as $z = 0$, then we require solution of the equations

$$dt = \frac{dx}{v_x} = \frac{dy}{v_y} = \frac{dz}{v_z} \tag{1}$$

with

$$t - z/u \to 0 \quad \text{as} \quad z \to -\infty$$

where v_z is the z velocity and an undisturbed stream flow has the value

$$v_z = u, \; v_x = v_y = 0.$$

The velocities v_x, v_y, and v_z are found from

$$v_x = \frac{-\partial\phi}{\partial x}, \quad v_y = \frac{-\partial\phi}{\partial y} \quad v_z = \frac{-\partial\phi}{\partial z}$$

where ϕ is the velocity-potential solution of Laplace's equation.

This definition implies that far upstream material planes at right angles to the stream are planes of $t = \text{constant}$. This is the classical "drift function" discussed by Darwin (1953).

Consider flow past a spherical fireball vortex in which the velocity field far upstream from the obstacle is defined as

$$v_z = V(x,y) \quad v_y = v_x = 0. \tag{2}$$

The stream lines of the flow can be represented by equations of the form

$$x = x(x_0, y_0, z) \quad y = y(x_0, y_0, z) \tag{3}$$

where

$$x_0 = \lim_{z \to -\infty} (x) \quad , \quad y_0 = \lim_{z \to -\infty} (y) \; . \tag{4}$$

These are solutions of Equation 1. The solution for the variable t is

$$t = t(x_0, y_0, z) = \frac{z}{u} + \int_{-\infty}^{z} \left\{ \frac{1}{v_z(x_0, y_0, z)} - \frac{1}{u} \right\} dz \qquad (5)$$

where v_z is the z component of the velocity on the stream line given by Equation 3, and u is the undisturbed fluid velocity.

Given a point in the flow field outside of a sphere, the drift function can now be determined.

The drift function t' at a burst time T' can be found by subtracting the actual time difference ΔT between the calculation time T and the burst time T'. Once the new drift function t' is known, a new position can be found from it.

Using polar spherical coordinates r, θ, ϕ fixed at the center of the sphere, the Stokes stream function, LAMB (1932), is given for unit upward velocity as

$$\rho_0^2 = r^2 \sin^2\theta \, (1 - a^3/r^3) \qquad (5a)$$

where a is the radius of the sphere, ψ is equal to zero. It should be noted that $\rho_0 \to x$ as $x \to \infty$.

The solution for the drift function t can be obtained from either of the coupled ordinary differential equations

$$dt = \frac{dr}{v_r} = \frac{dr}{u\left(1 - \frac{a^3}{r^3}\right)\cos\theta} \qquad (6)$$

and

$$dt = \frac{rd\theta}{v_\theta} = -\frac{rd\theta}{u\left(1 + \frac{a^3}{r^3}\right)\sin\theta} \tag{7}$$

and on any given streamline

$$t + r/u \to 0 \quad \text{as} \quad \theta \to \pi \quad . \tag{8}$$

Although Equations (6) and (7) are hyper-elliptic, useful expressions can be obtained for large and small values of ρ_0/a.

For large ρ_0/a, Stokes stream function can be expanded in powers of a^3/r^3 as

$$r = \frac{\rho_0}{\sin\theta}\left(1 + \frac{1}{2}\frac{a^3}{r^3}\sin^3\theta - \frac{3}{8}\frac{a^6}{\rho_0^6}\sin^6\theta + \ldots\right) . \tag{9}$$

Using this expansion, Equation (7) can be expanded to give

$$udt = -\frac{\rho_0 d\theta}{\sin^2}\left(1 + \frac{3}{8}\frac{a^6}{\rho_0^6}\sin^6\theta - \frac{a^9}{\rho_0^9}\sin^9\theta + \frac{315}{128}\frac{a^{12}}{\rho_0^{12}}\sin^{12}\theta + \ldots\right) \tag{10}$$

Integrating, yields

$$ut = \rho_0 \operatorname{Cot}\theta + \frac{3}{8}\frac{a^6}{\rho_0^5}\int_\theta^\pi \sin^4 d\theta - \frac{a^9}{\rho_0^8}\int_\theta^\pi \sin^7 d\theta + \frac{315}{128}\frac{a^{12}}{\rho_0^{11}}\int_\theta^\pi \sin^{10}\theta d\theta - \ldots \tag{11}$$

The limits for the integral satisfy Equation (8). This series evaluation converges for all θ with the value $\rho_0/a > 1.375$.

The total drift function $Z(\rho_0)$ from Darwin (1953) is given as;

$$Z(\rho_0) = \lim_{z\to\infty} (ut-z) = \frac{3}{8}\ \frac{a^6}{\rho_0^5} \left(\frac{3\pi}{8}\right) - \frac{a^9}{\rho_0^8} \left(\frac{32}{35}\right) + \frac{315}{128}\ \frac{a^{12}}{\rho_0^{11}} \left(\frac{63\pi}{256}\right) \tag{12}$$

It should be noted that for any streamline

$$t(\theta) = 2t(\pi/2) - t(\pi - \theta)$$

and

$$\begin{aligned} Z(\rho_0) &= \lim_{\theta\to 0} (ut-z) = 2(ut)_{(\theta=\pi/2} - \lim_{\theta\to\pi} (ut-z) \\ &= 2(ut)_{\theta=\ \pi/2} \end{aligned} \tag{13}$$

For small values of ρ_0/a each streamline is divided into two parts. Part one for θ near 0 or π , and second one on which $(r/a - 1)$ is small.

When θ is near π, then $-\sec\theta \approx 1 + \frac{1}{2}\sin^2\theta$ in Equation (6) and using Equation (5) gives the value of

$$ut = -r + \frac{1}{6}\ \frac{\rho_0^2\ r^2/a^3}{(r/a)^3 - 1} - \frac{1}{3}\, a \left(1 + \frac{1}{3}\ \frac{\rho_0^2}{a^2}\right)$$

$$\ell n\ \frac{r/a - 1}{\sqrt{(r/a)^2 + r/a + 1}} - \frac{a}{\sqrt{3}} \left(1 - \frac{\rho_0^2}{3a}\right) \tan^{-1}\left[\frac{\sqrt{3}}{(1 + 2\ r/a)}\right]. \tag{14}$$

For the case when θ departs from π (or 0), $(r/a - 1)$ is small and the following approximation can be used.

$$\frac{r}{1 + \dfrac{a^3}{2r^3}} \simeq \frac{2}{3}\, a + \frac{4}{9}\ \frac{\rho_0^2}{a} \operatorname{cosec}^2\theta \quad . \tag{15}$$

This then gives the result

$$ut = \frac{1}{2} Z(\rho_0) + \frac{2}{3} a \left(1 + \frac{\rho_0^2}{3a^2}\right) \ell n \tan(\frac{1}{2}\theta) - \frac{2\rho_0^2}{9a} \cot\theta \operatorname{cosec}\theta \ . \qquad (16)$$

The value of the total drift function is then found from Equation (16) and (14) to be for small $(r/a - 1)$ to be

$$z(\rho_0) = \frac{4}{3} a \left(1 + \frac{\rho_0^2}{3a^2}\right) \ell n \frac{3^{3/4}\ (2a)}{\rho_0} - \left(2 + \frac{\pi}{3\sqrt{3}}\right) a + \left(\frac{\pi}{\sqrt{3}} - 1\right) \frac{\rho_0^2}{9a} \ . \qquad (17)$$

Equations (12), (13), (14), (16), and (17) can be used to calculate the drift function t for any given value of ρ_0, r and θ. For $\theta > 5/6\pi$ Equation (14) is used. For $1/2\ \pi < \theta < 5/6\ \pi$ and $r/a < 1.5$, Equation (16) is a good approximation. When $r/a > 1.75$ Equation (11) is valid. The gap between $1.5 < r/a < 1.75$ can be filled by interpolating Equations (16) and (11).

Lines of $t =$ constant drift function values are plotted in Figure 1. The horizontal lines were initially at right angles to the motion of the sphere. They are distorted around the sphere as it moves through the fluid. The plot was made in a coordinate system fixed with the rising sphere.

The lines of constant drift function show in detail where every particle is and when it is there. For example, if in polar spherical coordinates, a point is given as $r = 1.6$ and $\theta = -\pi/4$, the corresponding drift function can be found, which is say + 2.0, scaled to a unit fireball with unit rising velocity. It is requested to know where the point was 3.5 seconds before. This would put it on a drift function plane of -1.5 seconds, with the same stream function.

DRIFT FUNCTION

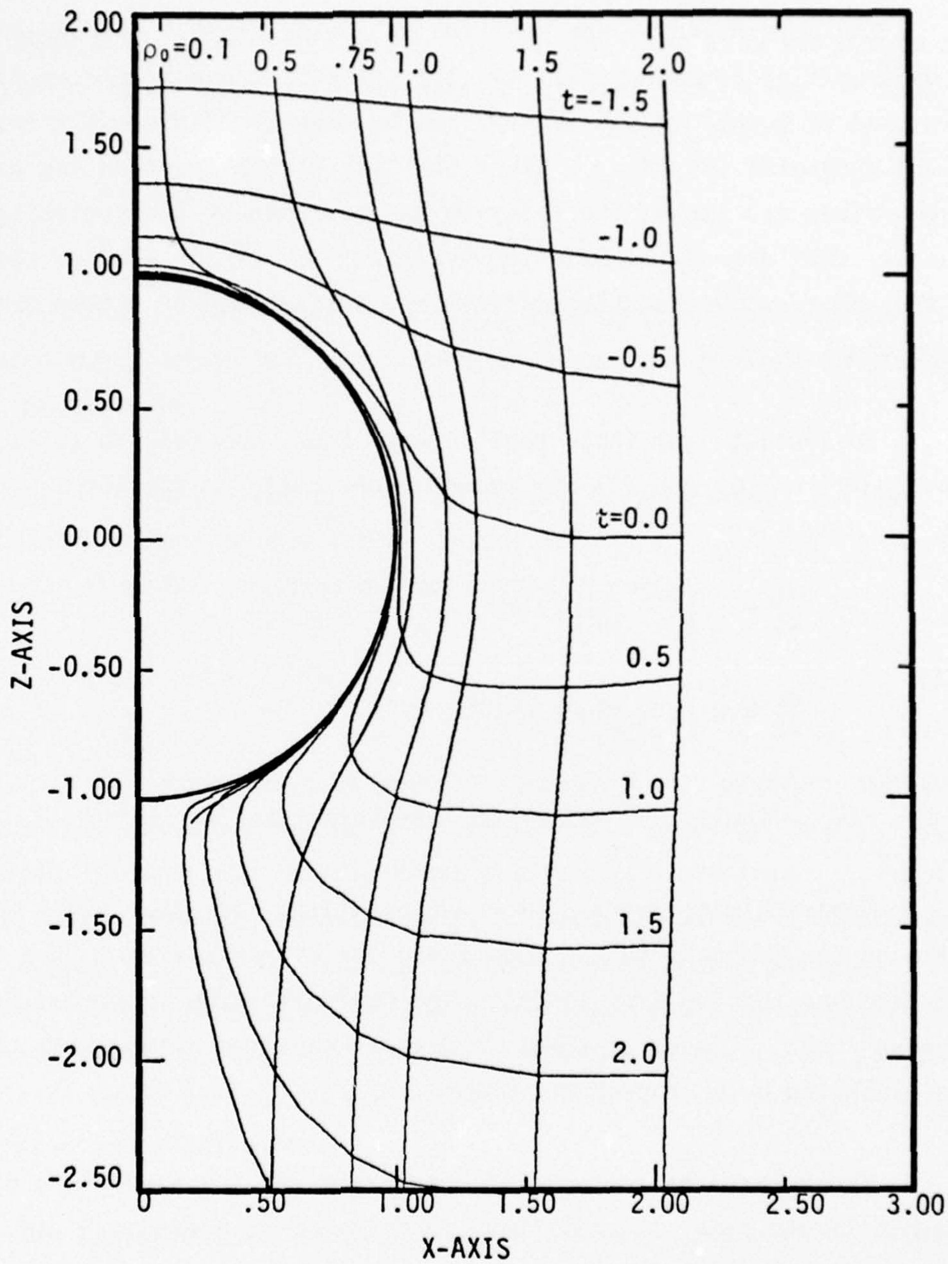


Figure 1. Plot of drift functions t and stream functions ψ for a unit sphere in a unit flow field. Coordinates of the intersection of t and ψ are stored in the table XX in Subroutine CIPHER, where $\psi = 1/2\ \rho_0^2$.

The corresponding new position at a time of -1.5 seconds can be found by inverting Equations (11) to (17), or more conveniently, a table of solutions of Equations (6) and (7) can be made for different stream functions and drift functions. Since both the stream function and drift function values are known, the solution can be found by interpolating from the table. Only one of the solution-variables r or θ need be stored since the other can be calculated from the constant Stokes stream function Equation (5a).

To generate the table that inverts Equations (11) to (17), the coupled Equations (6) and (7) are solved numerically in the form:

$$\frac{dr}{dt} = + \left(1 - \frac{a}{r^3}\right) \cos\theta \tag{18a}$$

$$\frac{d\theta}{dt} = - \left(1 + \frac{a}{2r^3}\right) \frac{\sin\theta}{r} \tag{18b}$$

where the rise velocity and radius a are both taken as unity.

Numerical integration of Equations (18a) and (18b) gives the position of the particle in the flow field for discrete times. The numerical method used was that of Gear (1971). The Gear algorithm is useful for solving stiff equations. It uses an Adams Predictor-Corrector method with the initial values generated by a Runge-Kutta method.

The polar spherical radial coordinate r was saved in a data table for each discrete time t and stream function ψ, where

$$\psi = \frac{1}{2} r^2 \sin^2\theta \left(1 - \frac{1}{r^3}\right) . \tag{19}$$

Thus for a given ψ and t, r can be found by a table look-up. Then θ can be found from the inversion of Equation (19) using r and ψ

$$\theta = \sin^{-1} \sqrt{\frac{1}{r^2} \frac{2\psi}{\left(1 - \frac{1}{r^3}\right)}} \tag{20}$$

Thus, the position is specified. The table look-up and interpolation is done in subroutine CIPHER and the outputs converted to fireball centered Cartesian coordinates.

Once the positions (z_q, x_q) in fireball coordinates is known, a simple Galilean transformation gives the position (Z_f, X_f, Y_f) in a coordinate system fixed at the position of the initial burst,

$$Z_f = Sr_1 - V_R + z_q \tag{21}$$

where Sr_1 is the slant range between the initial burst position and the present fireball position, V_R is the fireball rise velocity, and z_q is the z coordinate fixed at the initial burst position. Coordinates Y_f and X_f remain constant under the Galilean transformation in the z direction. The point defined by X_f, Y_f, and Z_f, in the initial burst position coordinates, is then rotated to the earth centered Cartesian coordinates. The vector position in this new frame is then added to the vector position of the initial burst giving the new vector position of the point in earth centered Cartesian coordinates.

The trajectory of the particles in a frame fixed with the stationary fluid are plotted in Figure 2 for some typical values of ρ_0(= .5, 1.0, 1.5, 1.8). From the figure, it can be seen that as the fireball passes the point, it is at its maximum lateral displacement. It should also be noted that as the fireball passes the point, the point takes on a retrograde motion.

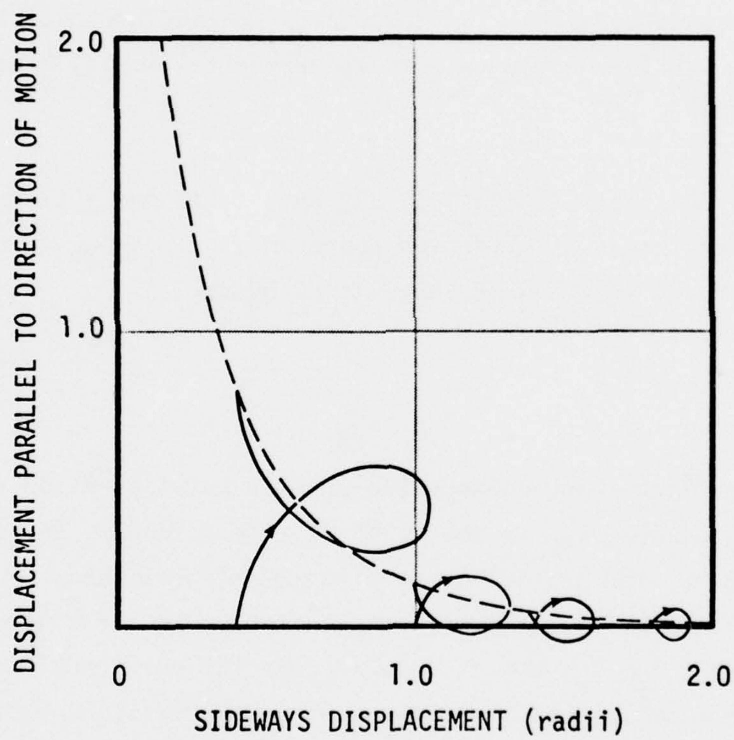


Figure 2. Plot of fluid particle displacements as seen in a coordinate system fixed with the fluid. The dotted line represents the total drift displacement after the passage of the unit sphere.

SHOCK DISPLACEMENT CALCULATIONS

The shock displacement is calculated after the point has been moved back in time to a burst time. It is assumed that the shock arrives instantaneously at the point of interest. This is a zeroth order approximation and will be changed to include the shock arrival time and shock duration. For calculation times long enough after burst time for shock traversal of the point, this assumption causes only a small error because of two facts: 1) if the fireball is very far away from the point, the shock displacement time is greatly in error, but the actual displacement is very small, 2) if the burst is close to the point, the timing error is small and the shock displacement is large.

The distance from the initial burst position to the point is scaled to dimensionless coordinates using a modified Sach's scaling

$$\alpha = .345 \left(W_{KT} \frac{P}{P_0}\right)^{1/3} e^{S_1/3H_s}$$

where W_{KT} is the yield in kilotons, P is the pressure at the point of interest, P_0 is the sea level pressure, S_1 is the height of the point above (+) or below (-) the fireball, H_s is the scale height. This expression reduces down to

$$\alpha = 13.6\, R_{H_0}\, e^{S_1/3H_s}$$

where R_{H_0} is the initial fireball radius at the end of the radiation phase.

Based on a fit to a RADFLO run (5KT at 9.15 km), a shock displacement $\Delta\lambda$ in scaled distance is given by

$$\Delta\lambda = 0.096\, (\lambda' \,(2+\lambda'))^{-1}$$

where $\lambda' = \lambda + \Delta\lambda$ is the final position in scaled units.

SECTION III

CODING CONSIDERATION FOR FLOW FIELD CALCULATIONS

CONTROL OF CALCULATIONS BY SUBPROGRAM HYDRO

The above mathematical method of calculating particle movements in the flow field around a rising fireball has been coded into eight subprograms for use in ROSCOE. The controlling routine is HYDRO, which is called with a given time and position.

Previous to a call to HYDRO, a call has been made to the burst environment module (PMDS) which sets up the vortex radii at the initial times and at the calling time. Also saved are all the fireball vortex positions at that time of call.

Given the position of a point, the time and pertinent fireball positions, HYDRO makes a call to subprogram EDITX to determine which bursts affect the given point.

EDITX begins the loop over all existing fireballs including those created by a hydromerge. If the burst was created by a hydromerge, it creates the initial vortex information for the merged fireball. It then calculates the distance of closest approach to the line connecting the initial fireball center and present center. If this radius scaled distance is greater than 1.8, it rejects this fireball for consideration. If the time it takes for the fireball to get to the point is very large, the event is rejected. If the point is more than a radius on front of the fireball, the burst is rejected. For all bursts accepted as influencing the given point, a count is kept (=NAI) and the fireball index is stored in the NCAG array.

HYDRO then begins to loop over all the bursts including bursts created during a hydromerge. It starts with the most recent burst time first and does the calculation back to this time. It then does the shock displacement calculation. It saves this new calculated position and puts it into the output array if the time was a burst time and not merely a merge time. The saved new position is now used to regress the calculation back to the second to the last occurring burst. This new position is saved and used to continue the calculation back to where the parcel was for the first burst before the arrival of any shock waves.

For each regression back to a burst time, an inner loop is made over all the fireballs that will influence the point during this time increment. After the time regression goes back beyond the burst time of an event affecting the point, this event is removed from the NCAG array, and the calculation continues with the remaining influencing fireballs.

When multiple events influence the point, the individual displacements from each burst are saved. After the inner loop over all influencing events is completed, a vector sum is made of all the individual displacements.

A check is made of the influencing fireball type flag KINDF to determine if the fireball is active at this time. If it is not active, i.e., has been radiation or hydromerged, then it is not used to calculate the change in position of the point PXYZ. After the calculation regresses back to the time of the merge for this fireball, the burst is used to determine the position.

CRITERIA FOR EDITING FIREBALLS

Before a flow field calculation is performed, a call is made to an editing routine. This routine loops over all the existing fireballs, active and inactive, and determines which fireballs will affect the given point. All fireballs that will ever have an affect on the point are stored in array NCAG.

If the distance of closest approach to the line of centers between the initial burst and present fireball position (scaled to the fireball) radius at the calculation time) is greater than 1.8, the fireball is rejected as not affecting the point.

If the point of interest is more than 1.5 radii above the fireball position at calculation time or 1.5 radii below the initial burst position, the burst is rejected.

SINGLE BURST CASE

For the single burst case, when EDITX returns NAI equal to 1 and NCAG(1) equal to 1, subprogram HYDRO begins the calculation of the effect of burst 1 on PXYZ. The burst will always be active since there is only one burst. Also the calculation can proceed back to the initial burst time in one pass through the routine.

Hydro calculates the distance of closest approach, DIST. It calculates the slant range S_{r1} along the line of centers between the initial burst position and the position at calling time, the slant range, S1, from burst point to point of closest approach; slant range, R_{ad}, from present burst position to point P_{xyz}. If the point is more than a fireball radius below the initial burst point, the effect of burst N on the point is considered negligible.

The radius of the fireball where most of the influence is occurring on point P_{xyz} is found by interpolating linearly between the initial and final radii:

$$R = (R_{in} S_{rd} + R_v S_1)/S_{r1}$$

where S_{rd} is the slant range from the present position of the fireball to the point of closest approach, R_{in} is the initial vortex radius, R_v is the present vortex radius.

MULTIPLE BURST CASE

The mathematical method for the case where two or more fireballs are affecting a point is handled similarly to the single burst case. The displacement calculation is done separately for each fireball. The final displacement is the vector sum displacement over all fireballs.

No attempt is made to account for the change in a fireball flow field due to another fireball flow field. It is expected that the effect is small except in cases where the fireballs are closer than .5 fireball radii.

SECTION IV

DESCRIPTION OF SUBPROGRAMS

Subroutine HYDRO is the main ROSCOE subprogram for calculating the particle time history in the flow field around a rising fireball.

Fireballs are edited as to their effect on the given point by EDITX.

Subprogram SYZYGY calculates the drift function t (=TOUT) for the initial given point.

Subprogram CIPHER calculates the position of the particle at a given drift function and stream function.

Subprogram SCHCK calculates the shock displacement of a given point by a given burst.

Description of Code HYDRO

Purpose

Subroutine HYDRO calculates the position of a given point at a given time at all burst times previous to the given time. This requires that the code run backwards in time.

Inputs to Subroutine HYDRO

Formal Argument

PXYZ(I) = 3 word array of coordinates x, y, z in cm.
Earth centered Cartesian with x through Greenwich

Inputs from Labeled Common

Block	Variable	Description
/RADDAT/	XIN(3,I)	Initial vector position of event I (cm)
	XEV(3,I)	Vector position of event I at time = TSIM (cm)
	REIN(I)	Initial vortex radius = 4* RHZERO
	REV(I)	Vortex radius of event I at time = TSIM (cm)
	VRZ(I)	Event rise velocity magnitude (cm/sec)
/EVXDAT/	NUMX	Number of real events
	TSIM	Time of calculation (sec)
/EVENTX/	NF	Total number of events at time = TSIM includes hydromerges
	TB(I)	Burst time of event I
/GEOTD/	KINDF(I)	Flag to indicate type of event
		= 1 spheroidal
		= 2 spheroidal, pressure equilibrium

		= 3 torus
		= 4 merged during radiation phase
		= 5 merged during hydrodynamic phase
	MRGID(I)	Flag to indicate index of merged events
	TCHAR(I)	Characteristic time for merged events
/SAVEVX/	BUFFR(15,I)	Initial event radius for the Ith event to which all parameters are scaled (=RHZERO(I)) in common block/EVENTX/

Output from Subroutine HYDRO

Formal Arguments

XARAY(3,N)	Vector position array for point PXYZ at all previous events (N=1,NVMX) (cm)
MODE	Flag to indicate significant fluid movement = 1 fluid has moved = 0 fluid has not moved significantly

External Subprograms Used in HYDRO

Name	Information requested/description
EDITX	Loops over all bursts and selects those that will affect point PXYZ
SYZYGY	Gives the time since the point passed the center of the burst (+) or the time it will take to pass the center of of the burst (-), scaled to radius of fireball
CIPHER	Calculates the position of the point for a given time in a coordinate system attached to the burst center and in the x-z plane. It does the calculation for a unit vortex radius and unit velocity.
EVENAD	Performs the vector addition of point displacement resulting from the multiple burst interactions.

SCHCK	Calculates the shock displacement from each burst on the point at the burst time.
ROOTT	Calculates the time at which a given stream function crosses the zero axis.
DISCAP	Calculates the distance of closest approach of the point to the line connecting centers. Calculates the needed slant ranges.

External Utility Subprograms Required

Name	
Vector package	
LOCLAX	Generates transformation matrix
XMIT	Copies vector A to B
XMAG	Gives magnitude of vector
SUBVEC	Subtracts two vectors
VECLIN	Adds two vectors
MATMULT	Does matrix multiple
DOT	Does Dot product
UNITV	Finds unit vector
CROSS	Finds cross product A×B
CROS1	Find cross product and normalizes to 1
PROJ	Finds projection of A on B
LOC1	Find SCM address
FDIV	Prevents division error abort
VECSUM	Vector sum
EFCGEO	Transforms from xyz to geographic coordinant
GEOEFC	Inverse of EFCGEO

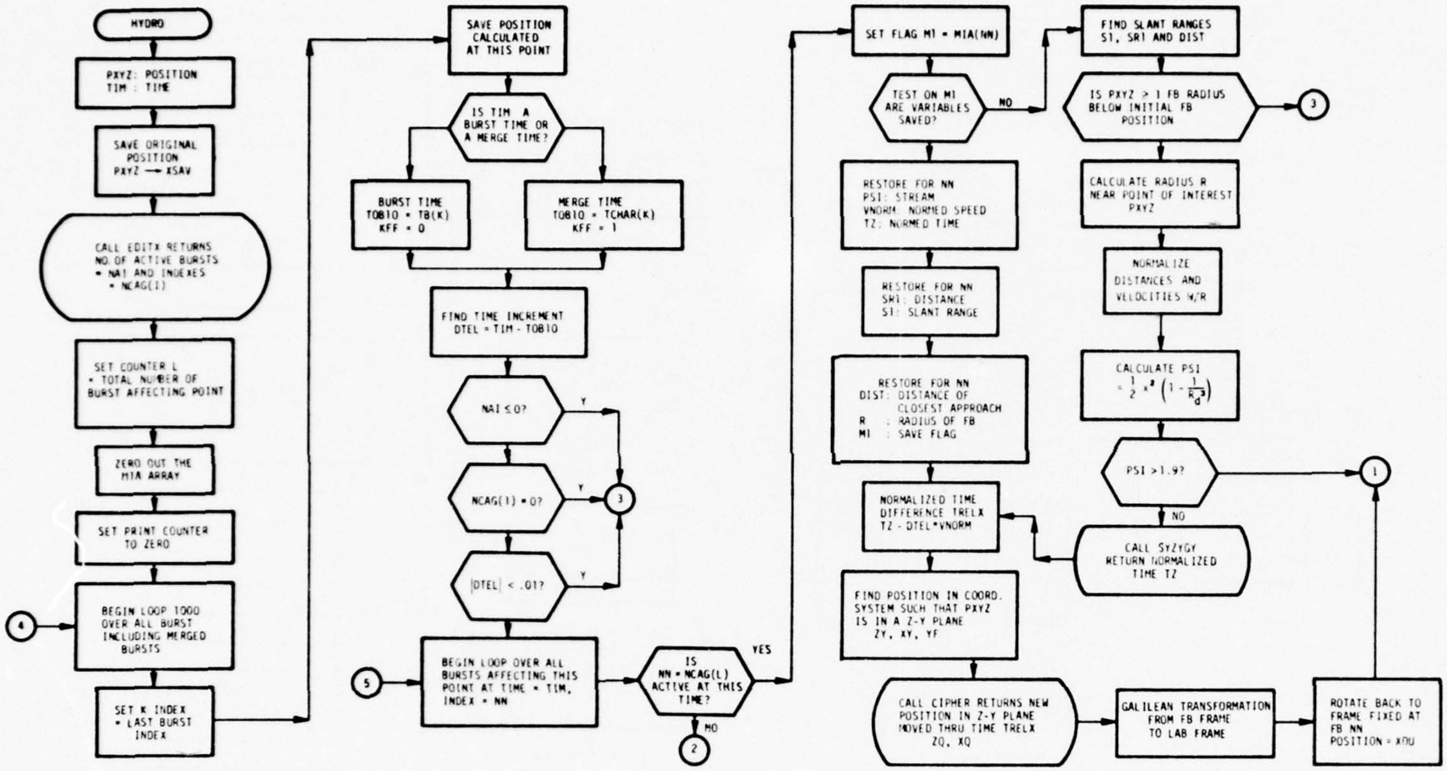
GLOSSARY OF VARIABLES

Roscoe Routine HYDRO

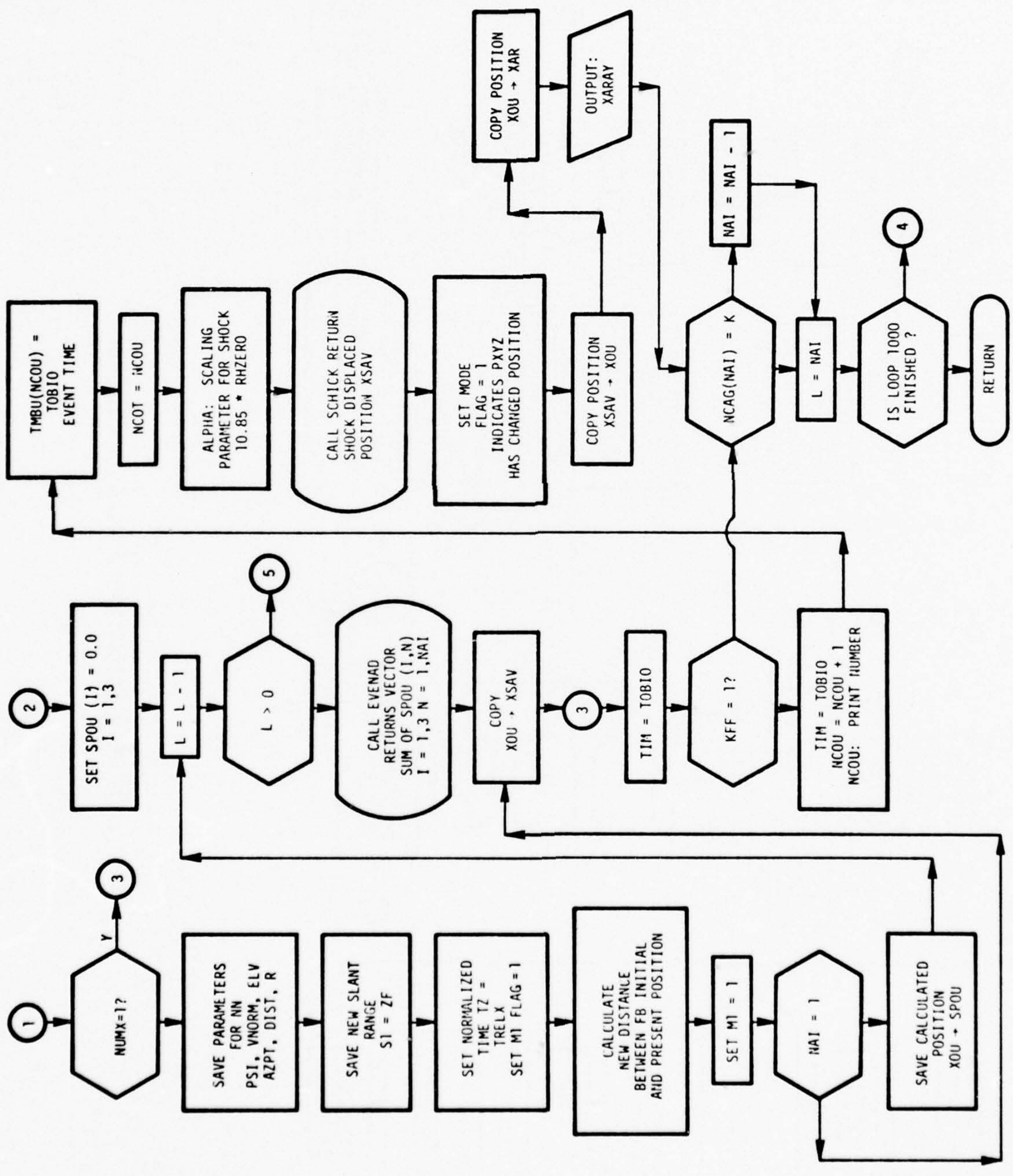
NAME	Description
PXYZ(3)	Input vector position
XARAY(3,I)	Output vector position at each burst time of Index I
MODE	Flag to indicate significant flow field movement
TIM	Calculation time local variable
TSIM	Global calculation time
XSAV(3)	Local Var., vector position array
M1	Flag to indicate data is saved for fireball vortex
L	Running index for burst index contained in NCAG
NAI	Return from EDITX, Number of burst affecting PXYZ
MiA(I)	Array of flags indicating data saved for burst I
NRUN	Dummy running variable for DO 1000
NX	Number of bursts up to time TIM
K	Index of burst starting with last burst first
XOU(3)	Local variable, array of vector position
KFF	Flag whether index K is for real burst or merged burst
TOBIO	Local variable set to the burst time or merge time
TB(K)	Burst time from/GEOTD/
DTEL	Time difference between present time and burst time
NCAG(10)	Array of burst indexes affecting PXYZ
NN	Running index of burst affecting point PXYZ
KINDF(10)	Array of flags describing fireball type/GEOTD/
TCHAR(10)	Characteristic burst or merge time for each fireball
PSI	Stream function
VNORM	Speed of fireball in effective vortex radii/sec

TZ	Relative time since passage of point past fireball (normalized by R)
SR1	Slant range of initial position to present position
S1	Slant range from initial position to PXYZ on line connecting centers
DIST	Distance of closest approach of PXYZ to line of centers
R	Radius of vortex near PXYZ used to scale distances
XIN(3,I)	Initial position of fireball vortex
XEV(3,I)	Final position of fireball vortex
RAD	Slant range from fireball position to PXYZ
REV(I)	Radius of vortex at calculation time
SRD	Slant range from fireball to point of closest approach
RH	Normalized distance of closest approach
RR	Radius normalized RAD
PSI	Stream function in unit velocity field
VRZ(I)	Speed of fireball unnormalized (cm/sec)
TRELX	Time difference scaled to fireball with unit rise
XF	X position in fireball centered coordinates of point PXYZ
YF	Y position in fireball centered coordinates of point PXYZ
ZF	Z position in fireball centered coordinates of point PXYZ
XQ	X positions of point at new time TIM
ZQ	Z positions of point at new time TIM
D(3)	Vector position of point PXYZ in initial fireball coordinates multiply used
CVEC(3,N)	Array of vectors from initial fireball N to final fireball N.
UVEC	Transformation matrix from XYZ to user frame
NRA	Row size of matrix
NCARB	Column size of matrix
NCB	Vector column size
POF(3)	Vector position in burst centered coordinates at time = TOBIO
NUMX	Number of actual bursts

SPOU(3,N)	Local array to store positions
TMBU(10)	Burst times in descending order
NCOT	Total number of print times
ALPHA	Shock scaling parameter



Flow Diagram for Subprogram HYDRO



1
NUMX=1?
Y
3
SAVE PARAMETERS FOR NN PSI, VNORM, ELV AZPT, DIST, R
SAVE NEW SLANT RANGE S1 = ZF
SET NORMALIZED TIME TZ = TRELX SET M1 FLAG=1
CALCULATE NEW DISTANCE BETWEEN FB INITIAL AND PRESENT POSITION
SET M1 = 1
NAI = 1
SAVE CALCULATED POSITION XOU → SPOU
2
SET SPOU (I) = 0.0 I = 1,3
L = L - 1
L > 0
5
CALL EVENAD RETURNS VECTOR SUM OF SPOU (I,N) I = 1,3 N = 1,NAI
COPY XOU → XSAV
3
TIM = TOBIO
KFF = 1?
TIM = TOBIO NCOU = NCOU + 1 NCOU: PRINT NUMBER
TMBU(NCOU) = TOBIO EVENT TIME
NCOT = NCOU
ALPHA: SCALING PARAMETER FOR SHOCK 10.85 * RHZERO
CALL SCHICK RETURN SHOCK DISPLACED POSITION XSAV
SET MODE FLAG = 1 INDICATES PXYZ HAS CHANGED POSITION
COPY POSITION XSAV → XOU
COPY POSITION XOU → XAR
OUTPUT: XARAY
NCAG(NAI) = K
NAI = NAI - 1
L = NAI
IS LOOP 1000 FINISHED ?
4
RETURN

Description of Code EDITX

Purpose

This subroutine loops over all existing fireballs at calling time and determines which fireball will affect the given point.

Inputs

PXYZ(3)	Vector position of point

Inputs from Common

XIN(3,L)	Initial position of fireball L
XEV(3,L)	Final position of fireball L
TB(L)	Burst time for event L

Outputs to Common

NAI	Number of bursts interacting with point
NCAG(I)	Array of burst indexes interacting I=1, NAI

Externals used

DISCAP	Calculates distance of closest approach

Method

EDITX is a simple routine which is called every time HYDRO is called.

It loops over all fireballs and calculates the distance of closest approach of the line connecting centers with the given point. The calculation is done in DISCAP.

Criteria

A point is rejected if it is greater than 1.8 final fireball radii from the line connecting centers.

It is rejected if it is 1.5 fireball radii above the final position or 1.5 radii below the initial position. The radius at call time is used.

Glossary of Variables

Name	
PXYZ(3)	Input-vector position
NAI	Output-number of burst affecting point
NCAG(L)	Output - array of burst indexes
L	Running variable over all bursts
NX	Total number of bursts
SR12	Slant range from final fireball position to initial
CVEC(3,L)	Vector from initial fireball position to final position
XIN(3,L)	Initial position vector
XEV(3,L)	Final position vector
DIST	Distance of closest approach to line of centers
S1	Distance from initial position to point of closest approach
TDIS	Time for fireball to travel from point of closest approach to intiial position
REV(L)	Final vortex radius (event L) (cm)
VRZ(L)	Speed of rise for event L (cm/sec)
TTEST	Time to go from point to 1.5 fireball radii below initial fireball position
NCO	Running variable

Description of Code SYZYGY

Purpose

This subroutine calculates the drift function TZ scaled to a unit fireball radius rising at unit speed, given a position.

Inputs

R	Radius of fireball
VR	Rise speed
PSI	Stream function (= $1/2\ \rho_0^2$)

Outputs

TOUT	Drift function

Outputs to Common

THETA	Angle to point measured from rise line
RR	Distance in radii R from fireball to point
RH	Distance of closest approach in R
VNORM	Speed scaled by R
XROZ	Total drift displacement
TZ	Drift function time (sec)

Method

See Section II

Glossary of Variables

Name

COSEC	Cosec of THETA
COTAN	Cotan of THETA
ROA	Equivalent to RO
RO	$= \rho_0$
XROZ	Total drift function
UTZ	Distance from reference (z=0)

All other variables are defined previously.

Description of Code CIPHER

Purpose

This subroutine calculates the position of a point in fireball coordinates for a given stream function and drift function.

Inputs

T	Drift function
PP	Stream function

Inputs from Common

THETA	Angle to point measured from line of rise
VNORM	Rise speed in radii
RH	Distance of closest approach in R
RR	Slant range from fireball to point

Outputs

X	Cartesian coordinate perpendicular to rise in R
Y	Cartesian coordinate parallel to rise in R

Method

The coupled equations (6) and (7) in Section II were solved and the r coordinate solution was stored in a table for 35 times and 15 stream functions.

Then for a given time (drift function) T and stream function PP, a value of r can be picked from the table.

The X and Y coordinates are now determined from the equation

$$X = \sqrt{\frac{2 \cdot PP * r^3}{r^3 - 1}}$$

and

$$y = \pm\sqrt{r^2 - x^2}.$$

The sign of Y is positive above the fireball center and negative below. Close to fireball the sign of Y is determined by finding the slope of the stream function dy/dx. For values of X far from the sphere function subprogram ROOTT is used to find the time at which the given stream function crosses the zero Z axis.

Glossary of Variables

Name	
T	Drift function
PP	Stream function $(= 1/2\,\rho_0^2)$
X	Output - Cartesian coordinates perpendicular
Y	Output - Cartesian coordinate parallel to rise
NFLAG	Flag to indicate if point has moved
TI(35)	Array of drift functions
PS(15)	Stream functions $(= 1/2\,\rho_0^2)$
XX(35,15)	Array of solutions for TI and PS(=r)
P	Local variable - stream function
NOFF	Flag indicates whether P is off table
ITOFF	Flag indicates whether T is off table
FT	Interpolation weight for T
FP	Interpolation weight for P
XN	Nth point to interpolate from
RQ	Interpolated solution r
XTEM2	X^2
YTEM2	r^2-x^2
INFLG	Flag indicates whether this is first or second pass through calculation
XS	Temporary x coordinate
DELX	Change in X from pass 1 to 2
DTEL	Time difference (sec)
TDIF	Time difference since it made it to edge of table
DNOM	$x^2-2\cdot P$

$$\left(y = \left[\left(\frac{x^2}{x^2-2\cdot P}\right)^{2/3} - x^2\right]^{1/2}\right)$$

Description of Code SCHCK

Purpose

This subroutine calculates the shock displacement of a given point from a given fireball

Inputs

XOU(3)	Initial position vector
K	Fireball index
ALPHA	Scaling parameter

Inputs from Common

XIN(3,L)	Initial position for fireball L
XEV(3,L)	Final position for fireball L

Output

XSAV	Vector position after displacement

Method

See Section II. It does not take into account the change in the fireball position resulting from the interaction of one fireball with another.

A more sophisticated shock routine should take into account the change in position of all other fireballs from the shock passage of the fireball under consideration. This however would slow down the calculations considerably by necessitating a NxN calculation of shock interactions and by causing a re-evaluation of flow field parameters for every burst.

The next order approximation will take into account the shock arrival time and duration.

Glossary of Variables

Name	
C(3)	Vector from fireball to point
SR	Magnitude of C
SRLAM	Scaled slant range
DLAM	Scaled shock displacement
SRNEW	Final slant range
XSAV	Final position after shock passage.

All other variables are defined previously.

Varriables Generated by MODEL and used by ROSCOE model HYDRO

Common Block Array Used

Block	Variable	Description
GEOTD	TCHAR(I)	Array of characteristic times for event I
	KINDF(I)	Type of event I, i.e., = 1 spheroidal = 2 spheroidal pressured equilibrium = 3 torus = 4 merged during radiation phase = 5 merged during hydrodynamic phase
	MRGID(I)	Flag to indicate merging For non-merged events (MRGID(I)=KINDF(I)) For merged events, MRGID(I) units digit contains the event index from which the merge took place; the tens digit the event index of the second event. The MRGID of the events from which the merged event occurred contains in the unit digit, the other event, in the tens digit the new event formed.
RADDAT	XIN(3,I)	Initial geocentric Cartesian coordinates with X through Greenwich for the event I, with ordering X,Y,Z, (cm).
	XEV(3,I)	Geocentric Cartesian coordinates of event I at the calling time
	REIN(I)	Initial vortex radius (cm)
	REV(I)	Vortex radius at calculation time(cm)
SAVEVX	BUFFR(15,I)	Initial event radius for the I^{th} event (cm) to which all parameters are scaled (=RHZERO(I)) in common block/EVENTX/

The output array XARAY is filled in time ascending order.

Running times for multi-event scenarios at relatively high altitude and high energies promise to be long. A five burst scenario with a hydromerge and radiation merge for example will run greater than 77 ms per call with multiple events affecting the point. (Run on a CDC 7600).

SECTION V

SUBPROGRAM LISTINGS

HYDRO

```
          SUBROUTINE HYDRO(PXYZ,XARAY,MODE)                                 HYDRO.2
      C                                                                     HYDRO.3
      C                                                                     HYDRO.4
      C   THIS SUBPROGRAM CALCULATES THE TIME HISTORY OF THE GIVEN POINT    HYDRO.5
      C   PXYZ AND RETURNS ITS POSITION AT EACH EVENT TIME.                 HYDRO.6
      C                                                                     HYDRO.7
      C   INPUT                                                             HYDRO.8
      C   PXYZ=ARRAY OF GEOCENTRIC CARTESIAN COORDINATES                    HYDRO.9
      C                                                                     HYDRO.10
      C                                                                     HYDRO.11
      C       OUTPUT                                                        HYDRO.12
      C   XARAY(3,I)  VECTOR POSITION OF EVENT I AT EVENT TIME.             HYDRO.13
      C                                                                     HYDRO.14
      C                                                                     HYDRO.15
          COMMON/EVXDAT/NUMX,NAI,XAR(3,10),NCAG(10),TSIM,NCOT,TMBU(10)      EVXDAT.2
      C                                                                     EVXDAT.3
      C       EVENTX PARAMETERS                                             EVENTX.2
          COMMON /EVENTX/ NX, IDX, TB(50), HB(50), GCB(50), GLB(50),        EVENTX.3
         1                IDGAD(50), RHOB(50), HSB(50), TEMB(50), VRISE(50),EVENTX.4
         2                RDZERO(50), RHZERO(50), RUZERO(50), BXB(50),      EVENTX.5
         3                BYB(50), BZB(50), LHVB(50),XALPHA(50), KALCH      EVENTX.6
          EQUIVALENCE(TCH(1),TB(1))                                         HYDRO.18
      C       TIME DEPENDENT MODEL PARAMETERS                               GEOTD.2
          COMMON /GEOTD/ NF, INDXF(50), RTF(50), RLF(50), HF(50), GCF(50),  GEOTD.3
         1              GLF(50), HMAXF(50), HMINF(50), KINDF(50), TILTF(50),GEOTD.4
         2              AGE(50), NDTA, INDXD(100), DLABL(100), KDR(100),    GEOTD.5
         3              HDR(100), RTBS(100), RLBS(100), HBS(100), KNBS(100),GEOTD.6
         4              GCBTA(100),GLBTA(100),TF(50),TCHAR(50),MRGID(50),   GEOTD.7
         5               XFR(50),YFR(50),ZFR(50),ROT(50)                    GEOTD.8
          DIMENSION TOB(1)                                                  HYDRO.20
          COMMON/RADDAT/XIN(3,10),XEV(3,10),REIN(10),REV(10),VXYZ(3,10),    RADDAT.2
         1    VRZ(10),CVEC(3,10)                                            RADDAT.3
      C                                                                     RADDAT.4
          COMMON/GEOMD/THETA,RR,RH,VNORM,DTEL,XROX,TZ                       GEOMD.2
      C                                                                     GEOMD.3
      C       MATHEMATICAL AND GEOPHYSICAL CONSTANTS                        CNSTNT.2
          COMMON /CNSTNT/ RE, PI, HALFPI, RADIAN, DEGPRD, GRE2              CNSTNT.3
          DIMENSION PXYZ(3),XSAV(3),XOU(3),UVEC(3,3),C(3),D(3),POF(3),      HYDRO.24
         1     SPCU(3,10),XARAY(3,10)                                       HYDRO.25
          COMMON/FLOW/PSIA(10),VNORMA(10),TZA(10),ELVA(10),AZPTA(10),       HYDRO.26
         1     SR1A(10),S1A(10),DISTA(10),RA(10),M1A(10)                    HYDRO.27
      C                                                                     HYDRO.28
          DATA TRAVL/1.E05/                                                 HYDRO.29
      C                                                                     HYDRO.30
      C   CALL UP THE EDIT ROUTINE TO ELIMINATE THE NON ESSENTIAL EVENTS    HYDRO.31
      C   FROM BEING CONSIDERED IN THE FLOW FIELD CALCULATIONS FOR THE POINTHYDRO.32
      C                                                                     HYDRO.33
          TIM=TSIM                                                          HYDRO.34
   6      CALL XMIT(3,PXYZ,XSAV)                                            HYDRO.35
  11      CALL EDITX(XSAV)                                                  HYDRO.36
  13      M1=1                                                              HYDRO.37
  14      L=NAI                                                             HYDRO.38
  16      DO 30 I=1,10                                                      HYDRO.39
  24      M1A(I)=0                                                          HYDRO.40
  25  30  CONTINUE                                                          HYDRO.41
  26      NCOU=0                                                            HYDRO.42
```

```
HYDRO
      27           DO 1000 NRUN=1,NX
      30           K=NX-NRUN+1
              C    LOOP OVER ALL EVENTS INCLUDING HYDROMERGED EVENTS.
              C
              C
              C       BEGIN
              C       DO MOST RECENT EVENT FIRST
      32           CALL XMIT(3,XSAV,XOU)
      35           KFF=0
      36           IF(KINDF(K).GT.3) GO TO 60
      44      40   IF(MRGID(K).EQ.K) GO TO 60
      46      50   TORIO=TCHAR(K)
      50           KFF=1
      51           GO TO 80
      52      60   TORIO=TB(K)
      54           KFF=0
      55      80   CONTINUE
      55           DTEL =TIM-TORIO
      57           IF(NAI.LE.0) GO TO 700
      61           IF(NCAG(1).EQ.0) GO TO 700
      62           IF(ABS(DTEL).LT.1.E-2) GO TO 700
      65     100   CONTINUE
      65           NN=NCAG(L)
              C
              C    IS NN ACTIVE AT THIS TIME
              C
      67           IF(KINDF(NN).LT.4) GO TO 105
      72           IF((TIM-TCHAR(NN)).LT.1.E-5) GO TO 105
      75           GO TO 685
      76     105   CONTINUE
      76           M1=M1A(NN)
     100           IF(M1.EQ.0) GO TO 110
              C
              C    RESTORE ALL VARIABLES FOR EVENT NN PREVIOUSLY SAVED
              C    THESE VARIABLES ARE REGENERATED FOR EACH CALL TO HYDRO
              C    AND NEED NOT BE SAVED IN THE MAIN OVERLAY.
              C
     102           PSI=PSIA(NN)
     103           VNORM=VNORMA(NN)
     104           TZ=TZA(NN)
     106           SR1=SR1A(NN)
     107           S1=S1A(NN)
     111           DIST=DISTA(NN)
     112           R=RA(NN)
     114           M1=M1A(NN)
     116           GO TO 200
     116     110   CONTINUE
              C
              C    GET DISTANCES FROM EVENT AND LINE OF CENTERS
              C
              C
              C    CALCULATE THE DISTANCE=DIST FROM THE LINE OF CENTERS TO THE POINT
              C    AND THE DISTANCE=RAD FROM THE FINAL EVENT POSITION TO THE POINT.
              C
     116           CALL DISCAP(XIN(1,NN),XEV(1,NN),PXYZ,D,S1,DIST,SR1)
     130           CALL SUBVEC(XEV(1,NN),PXYZ,C)
```

```
 136        RAD=XMAG(C)                                                HYDRO.99
       C    CALCULATE RADIUS OF EVENT AT TIME OF PASSAGE               HYDRO.100
 140        IF(S1.LT.-1.5*REV(K)) GO TO 700                            HYDRO.101
       C                                                               HYDRO.102
 150        SRD=SR1-S1                                                 HYDRO.103
 151        R=(REIN(NN)*SRD+REV(NN)*S1)/SR1                            HYDRO.104
 154        R=AMAX1(REIN(NN),AMIN1(REV(NN),R))                         HYDRO.105
 163        RH=DIST/R                                                  HYDRO.106
 164        RR=RAD/R                                                   HYDRO.107
       C                                                               HYDRO.108
       C    PSI IS CALCULATED FOR UNIT RADIUS AND VELOCITY             HYDRO.109
       C                                                               HYDRO.110
 165        PSI=0.5*RH*RH*(1.-1./RR**3)                                HYDRO.111
 172        IF(PSI.GT.1.90) GO TO 650                                  HYDRO.112
       C                                                               HYDRO.113
       C    FIND THE RELATIVE TIME                                     HYDRO.114
       C                                                               HYDRO.115
 175        SRD=-SRD                                                   HYDRO.116
 176        CALL SYZYGY(R,VRZ(NN),PSI,DIST,SRD,TZ)                     HYDRO.117
 203        VNORM=VRZ(NN)/R                                            HYDRO.118
       C                                                               HYDRO.119
       C    NORMALIZE THE TIME DIFFERENCE TO AN EVENT WITH UNIT RISE   HYDRO.120
       C                                                               HYDRO.121
 210   200  CONTINUE                                                   HYDRO.122
 210        TRELX=TZ-DTEL*VNORM                                        HYDRO.123
 213        XF=0.0                                                     HYDRO.124
 213        YF=DIST/R                                                  HYDRO.125
 215        ZF=S1                                                      HYDRO.126
 217        CALL CIPHER(TRELX,PSI,XO,ZO,NFLAG)                         HYDRO.127
 223        IF(NFLAG.EQ.1) GO TO 650                                   HYDRO.128
       C                                                               HYDRO.129
       C    DO GALILEAN TRANSFORMATION                                 HYDRO.130
       C                                                               HYDRO.131
       C                                                               HYDRO.132
       C                                                               HYDRO.133
 227        ZF=SR1-VRZ(NN)*DTEL+ZO*R                                   HYDRO.134
 233        YF=XO*R                                                    HYDRO.135
 235        CALL SUBVFC(PXYZ,XIN(1,NN),D)                              HYDRO.136
 241        IF(XMAG(D).LT.1.0) D(1)=100.                               HYDRO.137
 253        CALL LOCLAX(CVEC(1,NN),D,1,2,UVEC)                         HYDRO.138
 260        NRA=3                                                      HYDRO.139
 261        NCARB=3                                                    HYDRO.140
 262        NCB=1                                                      HYDRO.141
 263        POF(1)=ZF                                                  HYDRO.142
 264        POF(2)=YF                                                  HYDRO.143
 266        POF(3)=XF                                                  HYDRO.144
 267        A=1                                                        HYDRO.145
 271        B=1                                                        HYDRO.146
 273        CALL MATMULT(UVEC,POF,D,NRA,NCARB,NCB)                     HYDRO.147
 277        CALL VECLIN(A,XIN(1,NN),B,D,XOU)                           HYDRO.148
 306   650  CONTINUE                                                   HYDRO.149
 306        IF(NUMX.EQ.1) GO TO 700                                    HYDRO.152
 312        M1=1                                                       HYDRO.153
       C                                                               HYDRO.154
       C    SAVE THE FLOW FIELD PARAMETERS FOR EVENT NN                HYDRO.155
       C                                                               HYDRO.156
```

HYDRO

```
      312            MIA(NN)=MI                                                    HYDRO.157
      313            PSIA(NN)=PSI                                                  HYDRO.158
      314            VNORMA(NN)=VNORM                                              HYDRO.159
      316            DISTA(NN)=DIST                                                NOV70.1
      317            RA(NN)=R                                                      HYDRO.161
      321            MIA(NN)=MI                                                    HYDRO.162
      322            SIA(NN)=ZF                                                    HYDRO.163
      324      680   CONTINUE                                                      HYDRO.164
      325            TZA(NN)=TRELX                                                 HYDRO.165
      326            SRIA(NN)=SRI-VRZ(NN)*DTEL                                     HYDRO.166
      332            IF(NAI.EQ.1) GO TO 670                                        HYDRO.167
               C                                                                   HYDRO.168
               C     SAVE THE VECTOR DISPLACEMENT CALCULATED FOR EVENT NN=SPOU     HYDRO.169
               C                                                                   HYDRO.170
      334            CALL XMIT(3,XOU,SPOU(1,L))                                    HYDRO.171
      340            GO TO 686                                                     HYDRO.172
      343      685   CONTINUE                                                      HYDRO.173
      343            CALL XMIT(-3,0.0,SPOU(1,L))                                   HYDRO.174
      351      686   CONTINUE                                                      HYDRO.175
      351            L=L-1                                                         HYDRO.176
      353            IF(L.GT.0) GO TO 100                                          HYDRO.177
               C                                                                   HYDRO.178
               C     DO THE VECTOR ADDITION OF THE DISPLACEMENTS FOR PXYZ FROM MULTIPLEHYDRO.179
               C     EVENTS.                                                       HYDRO.180
               C                                                                   HYDRO.181
      355            CALL EVENAD(SPOU,NAI,PXYZ,XOU)                                HYDRO.182
      362      670   CONTINUE                                                      HYDRO.183
      362            CALL XMIT(3,XOU,XSAV)                                         HYDRO.184
      367      700   CONTINUE                                                      HYDRO.185
      367            TIM=TOBIO                                                     HYDRO.186
               C                                                                   HYDRO.187
               C     IS TIM AN EVENT TIME                                          HYDRO.188
               C                                                                   HYDRO.189
      370            IF(KFF.EQ.1) GO TO 900                                        HYDRO.190
      373            TIM=TOBIO                                                     HYDRO.191
      373            NCOU=NCOU+1                                                   HYDRO.192
      375            TMOU(NCOU)=TOBIO                                              HYDRO.193
      377            NCOT=NCOU                                                     HYDRO.194
      377            ALPHA=10.85*RHZERO                                            HYDRO.195
      401            CALL SCHCK(XOU,K,ALPHA,XSAV)                                  HYDRO.196
      404            CALL XMIT(3,XSAV,XOU)                                         HYDRO.197
      407            CALL XMIT(3,XOU,XAR(1,K))                                     HYDRO.198
      413            CALL XMIT(3,XOU,XARAY(1,K))                                   HYDRO.199
      423      900   CONTINUE                                                      HYDRO.200
      423            IF(NCAG(NAI).EQ.K)NAI=NAI-1                                   HYDRO.201
      427            L=NAI                                                         HYDRO.202
      430     1000   CONTINUE                                                      HYDRO.203
               C                                                                   HYDRO.204
               C     THE MODE SWITCH IS SET TO 1 TO INDICATE THAT THE POINT HAS    HYDRO.205
               C     UNDERGONE SOME MOVEMENT.  A CHECK IS MADE HERE TO DETERMINE   HYDRO.206
               C     IF THE MOTION IS SIGNIFICANT                                  HYDRO.207
               C                                                                   HYDRO.208
      433            XMI=0.0                                                       HYDRO.209
      433            MODE=0                                                        HYDRO.210
      434            DO 1200 II=1,NCOT                                             HYDRO.211
      436            CALL SUBVEC(XARAY(1,II),PXYZ,C)                               HYDRO.212
```

```
HYDRO
      444        XM1=XMAG(C)+XM1                                           HYDRO.213
      452  1200  CONTINUE                                                  HYDRO.214
      454        IF(XM1.GT.TRAVL) MODE=1                                   HYDRO.215
      460        RETURN                                                    HYDRO.216
      461        END                                                       HYDRO.217
```

SUBPROGRAM LENGTH

00652

FUNCTION ASSIGNMENTS

EDITX

```
              SUBROUTINE EDITX(PXYZ)                                          EDITX.2
        C                                                                     EDITX.3
        C         THIS SUBPROGRAM LOOPS THROUGH THE EVENTS IN STORAGE UP      EDITX.4
        C     TO THE SIMULATION TIME.                                         EDITX.5
        C     THE ARRAY OF PERTINENT EVENTS IS STORED IN NCAG                 EDITX.6
        C                                                                     EDITX.7
        C         INPUTS                                                      EDITX.8
        C              THROUGH COMM EVXDAT                                    EDITX.9
        C     NUMX=TOTAL NUMBER OF EVENTS UP TO TSIM                          EDITX.10
        C     TSIM=SIMULATION TIME                                            EDITX.11
        C                                                                     EDITX.12
        C         OUTPUTS                                                     EDITX.13
        C     NCAG=ARRAY OF NAI PERTINENT EVENT INDEXES                       EDITX.14
        C     NAI=NUMBER OF IMPORTANT EVENTS                                  EDITX.15
        C                                                                     EDITX.16
        C                                                                     EDITX.17
        C     THIS ROUTINE IS A FIRST CUT AT EDITING THE EVENTS.              EDITX.18
        C     THE CRITERIA USED ARE SIMPLE AND CAN REJECT EVENTS THAT SHOULD NOTEDITX.19
        C     BE REJECTED AND ACCEPT EVENTS THAT SHOULD BE REJECTED.          EDITX.20
        C                                                                     EDITX.21
        C     IF AN EVENT IS ACCEPTED AS INFLUENCING THE POINT HISTORY,IT     EDITX.22
        C     SHOULD BE CHECKED AFTER THE DETAILED CALCULATIONS HAVE BEGUN IN EDITX.23
        C     SUBROUTINE HYDRO.                                               EDITX.24
        C                                                                     EDITX.25
        C         TIME DEPENDENT MODEL PARAMETERS                             GEOTD.2
              COMMON /GEOTD/ NF, INDXF(50), RTF(50), RLF(50), HF(50), GCF(50), GEOTD.3
             1              GLF(50), HMAXF(50), HMINF(50), KINDF(50), TILTF(50),GEOTD.4
             2              AGE(50), NBTA, INDXD(100), DLABL(100), WDR(100),  GEOTD.5
             3              HDR(100), RTBS(100), RLBS(100), HBS(100), RNBS(100),GEOTD.6
             4              GCBTA(100),GLBTA(100),TF(50),TCHAR(50),MRGID(50), GEOTD.7
             5               XFR(50),YFR(50),ZFR(50),RUT(50)                  GEOTD.8
              COMMON/EVXDAT/NUMX,NAI,XAR(3,10),NCAG(10),TSIM,NCOT,TMBU(10)    EVXDAT.2
        C                                                                     EVXDAT.3
              COMMON/RADDAT/XIN(3,10),XEV(3,10),REIN(10),REV(10),VXYZ(3,10),  RADDAT.2
             1    VRZ(10),CVEC(3,10)                                          RADDAT.3
        C                                                                     RADDAT.4
              COMMON/GEOMD/THETA,RR,RH,VNORM,DTEL,XROX,TZ                     GEOMD.2
        C                                                                     GEOMD.3
        C         EVENTX PARAMETERS                                           EVENTX.2
              COMMON /EVENTX/ NX, IDX, TB(50), HB(50), GCB(50), GLB(50),      EVENTX.3
             1                IDGAD(50), RHOB(50), HSB(50), TEMB(50), VRISE(50),EVENTX.4
             2                RDZERO(50), RHZERO(50), RUZERO(50), BXB(50),    EVENTX.5
             3                BYB(50), BZB(50), LHVB(50),XALPHA(50), KALCH    EVENTX.6
              COMMON/REPORT/NAFFCT                                            NOV20A.71
              DIMENSION PXYZ(3),C(3),B(3),D(3),H(3)                           EDITX.31
              NAMELIST/EDIT3/PXYZ,C,L,SR12                                    EDITX.32
        C         BEGIN EVENT LOOP                                            EDITX.33
        C                                                                     EDITX.34
              NCO=0                                                           EDITX.35
    2         NAFFCT=0                                                        NOV20A.72
    3         NAI=1                                                           EDITX.36
    4         NCAG(1)=0                                                       EDITX.37
    6         DO 1000 L=1,NX                                                  EDITX.38
        C                                                                     EDITX.39
    7         SR12=XMAG(CVEC(1,L))                                            EDITX.40
   12            IF(SR12.LT.1.E4) GO TO 1000                                  EDITX.41
```

EDITX

```
         C                                                            EDITX.42
         C    IS THIS EVENT ACTIVE I. E. NOT A MERGED EVENT           EDITX.43
         C                                                            EDITX.44
   16    800  CONTINUE                                                EDITX.45
         C    LOAD EVENT PARAMETERS FOR THE EVENT L                   EDITX.46
         C                                                            EDITX.47
         C                                                            EDITX.48
         C    WILL THIS L EVENT EVER HAVE AN EFFECT ON POINT GIVEN,   EDITX.49
         C        BEGIN CALCULATION                                   EDITX.50
         C    CALCULATE DISTANCE OF CLOSEST APPROACH                  EDITX.51
         C                                                            EDITX.52
   16         CALL DISCAP(XIN(1,L),XEV(1,L),PXYZ(1),H,S1,DIST,SR21)   EDITX.53
   31         RDIS =DIST                                              EDITX.54
   32         TDIS=(SR21-S1)/VRZ(L)                                   EDITX.55
   36      -> IF(S1.LT.-1.5*REV(L))TDIS=8888.                         NOV15.1
   43         IF((SR21-S1).LT.-1.5*REV(L))TDIS=8555.                  EDITX.57
         C                                                            EDITX.61
         C    THE RADIUS REV(L) SHOULD NOT BE USED HERE.  R THE RADIUS CF THE   EDITX.62
         C    EVENT NEAR THE POINT OF INTEREST SHOULD BE USED.  HOWEVER, THIS   EDITX.63
         C    RADIUS R REQUIRES EXTENSIVE CALCULATION NOT DEEMED JUSTIFIED AT   EDITX.64
         C    THIS POINT IN THE HISTORY PROCESS.                      EDITX.65
         C                                                            EDITX.66
         C                                                            EDITX.67
   52         RH=RDIS/REV(L)                                          EDITX.68
   54         IF(RH.GT.1.8) GO TO 1000                                EDITX.69
   60         IF(TDIS.GT. 7777.) GO TO 1000                           EDITX.70
   63         TTEST=TSIM-TB(L)+1.5*REV(L)/VRZ(L)                      EDITX.71
   67         IF(TDIS.GT.TTEST) GO TO 1000                            EDITX.72
   73         NCO=NCO+1                                               EDITX.73
   74         NCAG(NCO)=L                                             EDITX.74
   76         NAI=NCO                                                 EDITX.75
   77    1000 CONTINUE                                                EDITX.76
         C                                                            EDITX.77
  102         NAFFCT=NAI                                              NOV20A.73
  103         RETURN                                                  EDITX.78
  104         END                                                     EDITX.79
```

EDITX

```
      SUBROUTINE EDITX(PXYZ)
C
C          THIS SUBPROGRAM LOOPS THROUGH THE EVENTS IN STORAGE UP
C     TO THE SIMULATION TIME.
C     THE ARRAY OF PERTINENT EVENTS IS STORED IN NCAG
C
C          INPUTS
C                THROUGH COMM EVXDAT
C     NUMX=TOTAL NUMBER OF EVENTS UP TO TSIM
C     TSIM=SIMULATION TIME
C
C          OUTPUTS
C     NCAG=ARRAY OF NAI PERTINENT EVENT INDEXES
C     NAI=NUMBER OF IMPORTANT EVENTS
C
C
C     THIS ROUTINE IS A FIRST CUT AT EDITING THE EVENTS.
C     THE CRITERIA USED ARE SIMPLE AND CAN REJECT EVENTS THAT SHOULD NOT
C     BE REJECTED AND ACCEPT EVENTS THAT SHOULD BE REJECTED.
C
C     IF AN EVENT IS ACCEPTED AS INFLUENCING THE POINT HISTORY,IT
C     SHOULD BE CHECKED AFTER THE DETAILED CALCULATIONS HAVE BEGUN IN
C     SUBROUTINE HYDRO.
C
C          TIME DEPENDENT MODEL PARAMETERS
      COMMON /GEOTD/ NF, INDXF(50), RTF(50), RLF(50), HF(50), GCF(50),
     1               GLF(50), HMAXF(50), HMINF(50), KINDF(50), TILTF(50),
     2               AGE(50), NDTA, INDXD(100), DLABL(100), HDR(100),
     3               HOR(100), RTBS(100), RLBS(100), HBS(100), RNBS(100),
     4               GCBTA(100),GLBTA(100),TF(50),TCHAR(50),MRGID(50),
     5                XFR(50),YFR(50),ZFR(50),ROT(50)
      COMMON/EVXDAT/NUMX,NAI,XAR(3,10),NCAG(10),TSIM,NCOT,THBU(10)
C
      COMMON/RADDAT/XIN(3,10),XEV(3,10),REIN(10),REV(10),VXYZ(3,10),
     1     VRZ(10),CVEC(3,10)
C
      COMMON/GEOMD/THETA,RR,RH,VNORM,DTEL,XROX,TZ
C
C          EVENTX PARAMETERS
      COMMON /EVENTX/ NX, IDX, TB(50), HB(50), GCB(50), GLB(50),
     1                  IDGAD(50), RHOB(50), HSB(50), TEMB(50), VRISE(50),
     2                  RDZERO(50), RHZERO(50), ROZERO(50), BXB(50),
     3                  BYB(50), BZB(50), LHVB(50),XALFHA(50), KALCH
      COMMON/REPORT/NAFFCT
      DIMENSION PXYZ(3),C(3),B(3),D(3),H(3)
      NAMELIST/EDITX/PXYZ,C,L,SR12
C          BEGIN EVENT LOOP
C
      NCO=0
2     NAFFCT=0
3     NAI=1
4     NCAG(1)=0
6     DO 1000 L=1,NX
C
7     SR12=XMAG(CVEC(1,L))
12         IF(SR12.LT.1.E4) GO TO 1000
```

SYZYGY

```
                SUBROUTINE SYZYGY(R,VR,PSI,DIST,SRD,TOUT)                          SYZYGY.2
          C                                                                        SYZYGY.3
          C     THIS SUBPROGRAM CALCULATES THE DRIFT FUNCTION = TOUT               SYZYGY.4
          C     FOR A GIVEN POINT RELATIVE TO A SPHERE.                            SYZYGY.5
          C                                                                        SYZYGY.6
          C         INPUTS                                                         SYZYGY.7
          C     R=RADIUS OF CURRENT EVENT AT TIME OF PASSAGE OF TP                 SYZYGY.8
          C     VR=RISE VELOCITY                                                   SYZYGY.9
          C     PSI=STREAM FUNCTIO VALUE                                           SYZYGY.10
          C         OUTPUTS                                                        SYZYGY.11
          C     TZ=TIME CONSTANT CONTOUR RELATIVE TO EVENT CENTER OF ZERO          SYZYGY.12
          C                                                                        SYZYGY.13
                COMMON/CONST/RE,PI,THRD,PZERO,AZERO,DZERO,TZERO,PIO2               CONST.2
          C                                                                        CONST.3
                COMMON/GEOMD/THETA,RR,RH,VNORM,DTEL,XROX,TZ                        GEOMD.2
          C                                                                        GEOMD.3
          C                                                                        SYZYGY.16
                DATA PIO2/1.5707963/                                               SYZYGY.17
          C                                                                        SYZYGY.18
          C     DIST IS A POSITIVE DEFINITE QUANTITY BY THE DEFINITION C           SYZYGY.19
          C     OF THE COORDINATE FRAME                                            SYZYGY.20
          C                                                                        SYZYGY.21
                PSI=AMAX1(PSI,5.E-7)                                               SYZYGY.22
    13          DIST=AMAX1(DIST,1.)                                                SYZYGY.23
    16          THETA=ATAN2(DIST,SRD)                                              SYZYGY.24
    23          IFLAG=0                                                            SYZYGY.25
    24          VNORM=VR/R                                                         SYZYGY.26
    26          RO=SQRT(2.0*PSI)                                                   SYZYGY.27
    31          COSEC=1./SIN(THETA)                                                SYZYGY.28
    40          COTAN=SRD/DIST                                                     SYZYGY.29
    41          ROA=RO                                                             SYZYGY.30
    43          RH=DIST                                                            SYZYGY.31
    44          RR=DIST*COSEC/R                                                    SYZYGY.32
    46          PRINT 1080,RR,R,ROA,SRD,PSI                                        SYZYGY.33
         1080   FORMAT(1X,*RR= *1PE12.5,* R=*1PE12.5,* ROA,SRD,PSI= *1P3E12.5)     SYZYGY.34
    72          IF(RO.LT.1.5)                                                      SYZYGY.35
               1XROZ=.444444*(3.+RO*RO)*ALOG(4.559/RO)-2.604+0.0907*RO*RO         SYZYGY.36
   106          IF(RO.GE.1.5)XROZ=.44178/ROA**5-.914/ROA**8+1.9026/ROA**11         SYZYGY.37
   126          IF(THETA.GT.2.617.OR.THETA.LT.0.52359) GO TO 200                   SYZYGY.38
   137          IF(RR.GT.1.75) GO TO 50                                            SYZYGY.39
   142          UTZ=XROZ/2.+.666666*(1.+(ROA**2)/3.)*ALOG(TAN(THETA/2.))           NOV20.2
               1     -.22222*ROA**2*COSEC*COTAN                                    NOV20.3
               1     +.2222*ROA**2*COSEC*COTAN                                     SYZYGY.41
   164          TZ=UTZ/VNORM                                                       SYZYGY.42
   165          TOT=TZ                                                             SYZYGY.43
   166          IFLAG=1                                                            SYZYGY.44
   167          IF(RR.GT.1.5) GO TO 100                                            SYZYGY.45
   176          IFLAG=0                                                            SYZYGY.46
   176          GO TO 300                                                          SYZYGY.47
   177   50     CONTINUE                                                           SYZYGY.48
   177   100    CONTINUE                                                           SYZYGY.49
   177          UTZ=-ROA*COTAN+XROZ                                                SYZYGY.50
   202          TZ=UTZ/VNORM                                                       SYZYGY.51
   203          IF(IFLAG.EQ.1) GO TO 500                                           SYZYGY.52
   206          GO TO 300                                                          SYZYGY.53
   206   200    CONTINUE                                                           SYZYGY.54
```

SYZYGY

```
     206          RR=-RR                                                        SYZYGY.55
     207          RAB=ABS(RR-1)                                                 SYZYGY.56
     212          UTZ=-RR+.166666*(RO*RR)**2/(RR**3-1.)-.111111*(3.+RO**2)*     SYZYGY.57
                 1   ALOG(RAB/SQRT(RR*RR+RR+1))-.19245*(3.-RO*RO)*ATAN(1.73205  SYZYGY.58
                 2    /(1.+2.*RR))                                              SYZYGY.59
     252          RR=-RR                                                        SYZYGY.60
     253          UTZ=UTZ*R                                                     SYZYGY.61
     254          TZ=UTZ/VR                                                     SYZYGY.62
     255          IF(THETA.LT.PIO2) TZ=-TZ                                      NOV17.1
     261          IF(THETA.LT.PIO2)TZ=XROZ/VNORM+TZ                             SYZYGY.65
     266   300    CONTINUE                                                      NOV20.4
     266          TZ=TZ*VNORM                                                   SYZYGY.66
     270          TOUT=TZ                                                       SYZYGY.67
     271          RETURN                                                        SYZYGY.68
     271   500    CONTINUE                                                      SYZYGY.69
     271          TZ=((RR-1.5)*TOT+(1.75-RR)*TZ)*4.                             SYZYGY.70
     277          TZ=TZ*VNORM                                                   SYZYGY.72
     300          TOUT=TZ                                                       SYZYGY.73
     301          RETURN                                                        SYZYGY.74
     302          END                                                           SYZYGY.75
```

SUBPROGRAM LENGTH

00412

CIPHER

```
      SUBROUTINE CIPHER(T,PP,X,Y,NFLAG)                                 CIPHER.2
C                                                                       CIPHER.3
C     THIS SUBROUTINE CALCULATES THE POSITION OF A POINT IN             CIPHER.4
C     COORDINATES FIXED WITH THE SPHERE FOR A GIVEN STREAM              CIPHER.5
C     FUNCTION PP AND A GIVEN DRIFT FUNCTION T (SEC)                    CIPHER.6
C                                                                       CIPHER.7
C         INPUTS                                                        CIPHER.8
C     T=DRIFT FUNCTION IN SEC SCALED TO A UNIT RESE VELOCITY.           CIPHER.9
C     P=STREAM FUNCTION FOR UNIT EVENT RADIUS AND UNIT VELOCITY         CIPHER.10
C                                                                       CIPHER.11
C         OUTPUTS                                                       CIPHER.12
C     X=COORDINATE RELATIVE TO EVENT CENTER AND PERPENDICULAR TO        CIPHER.13
C         RISE VELOCITY                                                 CIPHER.14
C     Y=LONGITUDINAL COORDINATE AT TIME T IN UNITS RELATIVE TO          CIPHER.15
C         UNIT RADIUS AND RISE VELOCITY.                                CIPHER.16
C     NFLAG=FLAG TO INDICATE WHETHER ANY CHANGE IN POSITION HAS OCCURREDCIPHER.17
C                                                                       CIPHER.18
      COMMON/CONST/RE,PI,THRD,PZERO,AZERO,DZERO,TZERO,PIO2              CONST.2
C                                                                       CONST.3
      COMMON/GEOMD/THETA,RR,RH,VNORM,DTEL,XROX,TZ                       GEOMD.2
C                                                                       GEOMD.3
C                                                                       CIPHER.21
      DIMENSION TI(35),PS(15),XX(35,15)                                 CIPHER.22
      DATA TI/-10.,-5.,-4.,-3.,-2.5,-2.,-1.8,-1.4,-1.,-.8,              CIPHER.23
     A    -.3,-.2,0.0,.2,.4,.8,1.,1.3,1.6,2.,2.5,3.,4.,5.,6.,8.,10.,14.,CIPHER.24
     B    16.,18.,22.,25.,30.,40.,50./                                  CIPHER.25
      DATA PS/5.E-7,1.25E-5,5.E-5,1.25E-3,5.E-3,1.125E-2,               CIPHER.26
     A     2.E-2,.045,.08,0.125,.180,.320,.5,1.125,2.01/                CIPHER.27
      DATA NP/15/,NT/35/                                                CIPHER.28
      DATA TLAST/-10./,RLAS3/1.41492/,RL2/100.0660/                     CIPHER.29
      DATA(XX(I),I=1,114)/                                              CIPHER.30
     R  10.00278,   5.01770,   4.02877,   3.05222,   2.57502,   2.11466,CIPHER.31
     R   1.93880,   1.61192,   1.34001,   1.23451,   1.07335,   1.05627,CIPHER.32
     R   1.03242,   1.01830,   1.01021,   1.00312,   1.00172,   1.00070,CIPHER.33
     X   1.00028,   1.00009,   1.00002,   1.00001,   1.00001, 1.00001, CIPHER.34
     R   1.00001,   1.00537,   1.59866,   5.39738,   7.38934,   9.38586,CIPHER.35
     R  13.38297,  16.38204,  21.38127,  31.38069,  41.38047,  10.00278,CIPHER.36
     R   5.01770,   4.02878,   3.05223,   2.57502,   2.11467,   1.93880,CIPHER.37
     R   1.61193,   1.34001,   1.23451,   1.07334,   1.05626,   1.03241,CIPHER.38
     R   1.01830,   1.01021,   1.00312,   1.00172,   1.00070,   1.00029,CIPHER.39
     R   1.00009,   1.00002,   1.00001,   1.00002,   1.00042,   1.00814,CIPHER.40
     R   1.70788,   3.56048,   7.52952,   9.52620,  11.52445,  15.52276,CIPHER.41
     R  18.52214,  23.52159,  33.52113,  43.52095,  10.00278,   5.01771,CIPHER.42
     R   4.02879,   3.05224,   2.57504,   2.11468,   1.93882,   1.61195,CIPHER.43
     R   1.34003,   1.23453,   1.07337,   1.05629,   1.03243,   1.01832,CIPHER.44
     R   1.01023,   1.00314,   1.00173,   1.00072,   1.00030,   1.00010,CIPHER.45
     R   1.00004,   1.00004,   1.00034,   1.00650,   1.10642,   2.52494,CIPHER.46
     R   4.46962,   8.45148,  10.44906,  12.44770,  16.44632,  19.44580,CIPHER.47
     R  24.44531,  34.44489,  44.44473,  10.00290,   5.01795,   4.02908,CIPHER.48
     R   3.05262,   2.57549,   2.11522,   1.93939,   1.61260,   1.34073/CIPHER.49
      DATA(XX(I),I=115,228)/                                            CIPHER.50
     R   1.23522,   1.07395,   1.05684,   1.03294,   1.01879,   1.01068,CIPHER.51
     R   1.00357,   1.00217,   1.00118,   1.00066,   1.00101,   1.00268,CIPHER.52
     R   1.01030,   1.14920,   1.76042,   2.65773,   4.60878,   6.59656,CIPHER.53
     R  10.58945,  12.58812,  14.58730,  18.58638,  21.58600,  26.58562,CIPHER.54
     R  36.58528,  46.58513,  10.00328,   5.01869,   4.03000,   3.05383,CIPHER.55
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CIPHER

```
     R   2.57690,   2.11690,   1.94119,   1.61464,   1.34290,   1.23738,CIPHER.56
     R   1.07578,   1.05859,   1.03454,   1.02030,   1.01213,   1.00507,CIPHER.57
     R   1.00382,   1.00335,   1.00432,   1.00946,   1.03437,   1.12317,CIPHER.58
     R   1.69081,   2.57511,   3.53763,   5.51328,   7.50543,  11.50009,CIPHER.59
     R  13.49899,  15.49828,  19.49745,  22.49709,  27.49672,  37.49637,CIPHER.60
     R  47.49620,  10.00390,   5.01993,   4.03154,   3.05584,   2.57925,CIPHER.61
     R   2.11969,   1.94418,   1.61803,   1.34653,   1.24096,   1.07884,CIPHER.62
     R   1.06152,   1.03727,   1.02291,   1.01472,   1.00811,   1.00750,CIPHER.63
     R   1.00919,   1.01535,   1.03923,   1.13319,   1.35864,   2.13803,CIPHER.64
     R   3.07561,   4.05174,   6.03393,   8.02747,  12.02270,  14.02165,CIPHER.65
     R  16.02095,  20.02011,  23.01973,  28.01934,  38.01894,  48.01875,CIPHER.66
     R  10.00478,   5.02167,   4.03370,   3.05865,   2.58255,   2.12359,CIPHER.67
     R   1.94837,   1.62277,   1.35160,   1.24600,   1.08318,   1.06571,CIPHER.68
     R   1.04121,   1.02674,   1.01866,   1.01353,   1.01439,   1.02134/CIPHER.69
      DATA(XX(I),I=229,342)/                                            CIPHER.70
     R   1.03949,   1.10053,   1.28610,   1.60857,   2.47147,   3.42785,CIPHER.71
     R   4.40937,   6.39435,   8.38847,  12.38385,  14.38278,  16.38205,CIPHER.72
     R  20.38115,  23.38074,  28.38029,  38.37983,  48.37959,  10.00727,CIPHER.73
     R   5.02662,   4.03984,   3.06667,   2.59193,   2.13472,   1.96028,CIPHER.74
     R   1.63627,   1.36608,   1.26042,   1.09592,   1.07808,   1.05311,CIPHER.75
     R   1.03877,   1.03171,   1.03332,   1.04245,   1.07264,   1.13499,CIPHER.76
     R   1.29189,   1.60949,   2.01560,   2.93661,   3.90663,   4.89223,CIPHER.77
     R   6.87916,   8.87346,  12.86855,  14.86732,  16.86645,  20.86533,CIPHER.78
     R  23.86479,  28.86419,  38.86352,  48.86316,  10.01077,   5.03355,CIPHER.79
     R   4.04843,   3.07786,   2.60501,   2.15021,   1.97687,   1.65507,CIPHER.80
     R   1.38633,   1.28071,   1.11444,   1.09627,   1.07114,   1.05772,CIPHER.81
     R   1.05329,   1.06916,   1.09282,   1.15617,   1.27046,   1.49754,CIPHER.82
     R   1.87465,   2.30920,   3.24878,   4.22308,   5.20970,   7.19660,CIPHER.83
     R   9.19043,  13.18474,  15.18323,  17.18214,  21.18068,  24.17996,CIPHER.84
     R  29.17912,  39.17816,  49.17763,  10.01526,   5.04245,   4.05944,CIPHER.85
     R   3.09220,   2.62174,   2.16999,   1.99604,   1.67905,   1.41229,CIPHER.86
     R   1.30688,   1.13916,   1.12080,   1.09603,   1.08455,   1.08446,CIPHER.87
     R   1.12028,   1.16129,   1.26093,   1.41029,   1.67648,   2.08024,CIPHER.88
     R   2.52632,   3.47281,   4.44806,   5.43442,   7.42030,   9.41327/CIPHER.89
      DATA(XX(I),I=343,456)/                                            CIPHER.90
     R  13.40644,  15.40455,  17.40316,  21.40126,  24.40029,  29.39916,CIPHER.91
     R  39.39783,  49.39707,  10.02075,   5.05330,   4.07287,   3.10963,CIPHER.92
     R   2.64205,   2.19396,   2.02367,   1.70806,   1.44385,   1.33891,CIPHER.93
     R   1.17047,   1.15211,   1.12824,   1.11955,   1.12496,   1.18233,CIPHER.94
     R   1.23923,   1.36519,   1.53785,   1.82478,   2.24095,   2.69178,CIPHER.95
     R   3.64010,   4.61468,   5.60004,   7.58423,   9.57601,  13.56773,CIPHER.96
     R  15.56537,  17.56361,  21.56116,  24.55990,  29.55840,  39.55661,CIPHER.97
     R  49.55557,  10.03470,   5.08082,   4.10664,   3.15360,   2.69313,CIPHER.98
     R   2.25400,   2.08778,   1.78056,   1.52316,   1.42013,   1.25288,CIPHER.99
     R   1.23510,   1.21420,   1.21208,   1.22862,   1.32137,   1.39935,CIPHER.100
     R   1.55433,   1.74818,   2.05077,   2.47381,   2.92530,   3.86997,CIPHER.101
     R   4.84030,   5.82216,   7.80141,   9.79000,  13.77791,  15.77434,CIPHER.102
     R  17.77163,  21.76779,  24.76577,  29.76335,  39.76039,  49.75866,CIPHER.103
     R  10.05262,   5.11599,   4.15013,   3.20929,   2.75753,   2.32925,CIPHER.104
     R   2.16791,   1.87086,   1.62244,   1.52265,   1.36017,   1.34346,CIPHER.105
     R   1.32585,   1.32920,   1.35353,   1.46565,   1.55254,   1.71711,CIPHER.106
     R   1.91557,   2.21870,   2.63812,   3.08465,   4.02019,   4.98367,CIPHER.107
     R   5.96049,   7.93301,   9.91738,  13.90034,  15.89520,  17.89126,CIPHER.108
     R  21.88563,  24.88264,  29.87903,  39.87459,  49.87196,  10.11457/CIPHER.109
      DATA(XX(I),I=457,525)/                                            CIPHER.110
     R   5.23628,   4.29710,   3.39586,   2.97102,   2.57531,   2.42845,CIPHER.111
```

```
                R   2.16152,   1.94138,   1.85344,   1.71171,   1.69802,   1.68604,CIPHER.112
                R   1.69475,   1.72397,   1.84103,   1.92636,   2.08317,   2.26895,CIPHER.113
                R   2.55155,   2.94496,   3.36831,   4.26789,   5.20623,   6.16499,CIPHER.114
                R   8.11373,  10.08331,  14.04899,  16.03838,  18.03018,  22.01832,CIPHER.115
                R  25.01105,  30.00420,  39.99458,  49.98884,  10.20067,   5.40025,CIPHER.116
                R   4.49495,   3.64163,   3.24767,   2.88767,   2.75615,   2.52048,CIPHER.117
                R   2.32974,   2.25454,   2.13509,   2.12387,   2.11468,   2.12328,CIPHER.118
                R   2.14947,   2.25228,   2.32699,   2.46478,   2.62943,   2.88317,CIPHER.119
                R   3.24265,   3.63623,   4.48908,   5.39416,   6.32867,   8.24501,CIPHER.120
                R  10.19420,  14.13592,  16.11770,  18.10355,  22.06299,  25.07190,CIPHER.121
                R  30.05837,  40.04150,  50.03140/                                 CIPHER.122
          C                                                                        CIPHER.123
          C       BEGIN INTERPOLATION OF X IN TABLE AT TIME T AND STREAM PSI.      CIPHER.124
          C                                                                        CIPHER.125
                  INFLG=0                                                          CIPHER.126
      7           P=PP                                                             CIPHER.127
     11    10     CONTINUE                                                         CIPHER.128
     11           NFLAG=0                                                          CIPHER.129
     12           NOFF=0                                                           CIPHER.130
     12           IF(P.LT.PS(1)) NOFF=1                                            CIPHER.131
     16           IF(NOFF.EQ.1)P=PS(1)                                             CIPHER.132
     21           DO 200 N=2,NP                                                    CIPHER.133
     23           N2=N                                                             CIPHER.134
     24           IF(P.LE.PS(N)) GO TO 210                                         CIPHER.135
     27   200     CONTINUE                                                         CIPHER.136
     31           NOFF=2                                                           CIPHER.137
     32   210     CONTINUE                                                         CIPHER.138
     33           FP=(PS(N2)-P)/(PS(N2)-PS(N2-1))                                  CIPHER.139
          C                                                                        CIPHER.140
          C       THERE NEED BE NO RESTRICTIONS ON FP IF THE INTERPOLATION - EXTRAP-CIPHER.141
          C       OLATION IS LOGARITHMIC.                                          CIPHER.142
          C                                                                        CIPHER.143
     37           ITOFF=0                                                          CIPHER.144
     37           IF(T.LT.TI(1))ITOFF=1                                            CIPHER.145
     43           DO 300 I=2,NT                                                    CIPHER.146
     45           N1=I                                                             CIPHER.147
     46           IF((T-TI(I)).LE.1.E-4) GO TO 310                                 CIPHER.148
     52   300     CONTINUE                                                         CIPHER.149
     54           ITOFF=2                                                          CIPHER.150
     55   310     CONTINUE                                                         CIPHER.151
     55           IPAD=NOFF+1                                                      CIPHER.152
     57           NADD=ITOFF+1                                                     CIPHER.153
     61           GO TO (410,420,440),NADD                                         CIPHER.154
     67   410     GO TO (460,460,500),IPAD                                         CIPHER.155
     76   420     GO TO (560,560,500),IPAD                                         CIPHER.156
    105   440     GO TO (520,520,500),IPAD                                         CIPHER.157
    114   460     CONTINUE                                                         CIPHER.158
    122           FT=(TI(N1)-T)/(TI(N1)-TI(N1-1))                                  CIPHER.159
    126           FT=AMAX1(0.,AMIN1(FT,1.))                                        CIPHER.160
    135           A1=FP*FT                                                         CIPHER.161
    136           A2=(1.-FT)*FP                                                    CIPHER.162
    137           A3=FT*(1.-FP)                                                    CIPHER.163
    141           A4=(1.-FT)*(1.-FP)                                               CIPHER.164
    142           X1=XX(N1-1,N2-1)                                                 CIPHER.165
    144           X2=XX(N1,N2-1)                                                   CIPHER.166
    145           X3=XX(N1-1,N2)                                                   CIPHER.167
```

CIPHER

```
   147        X4=XX(N1,N2)                                                          CIPHER.168
   151        RG=SQRT(ABS(A1*X1**2+A2*X2**2+A3*X3**2+A4*X4**2))                     CIPHER.169
   171        R2=RQ*RQ                                                              CIPHER.170
   171        R3=RQ*R2                                                              CIPHER.171
   172        XTEM2=2.*P*R3/(R3-1)                                                  CIPHER.172
   177        X=SQRT(XTEM2)                                                         CIPHER.173
   204        YTEM2=R2-XTEM2                                                        CIPHER.174
   206        IF(YTEM2.LT.0.0)YTEM2=0.0                                             CIPHER.175
   211        Y=-SQRT(YTEM2)*1.017                                                  CIPHER.176
   220        IF(INFLG.EQ.1) GO TO 470                                              CIPHER.177
   222        IF(RQ.GT.1.065) GO TO 480                                             CIPHER.178
   225        INFLG=1                                                               CIPHER.179
   225        P=PP+.001*PP                                                          CIPHER.180
   230        XS=X                                                                  CIPHER.181
   231        GO TO 10                                                              CIPHER.182
   232  470   CONTINUE                                                              CIPHER.183
   232        DELX=X-XS                                                             CIPHER.184
   234        X=XS                                                                  CIPHER.185
   234        IF(DELX.GT.0.0) Y=-Y                                                  CIPHER.186
   237        GO TO 800                                                             CIPHER.187
   240  480   CONTINUE                                                              CIPHER.188
        C                                                                           CIPHER.189
        C     THE FACTOR 1.017 IS  HERE BECAUSE OF THE SLIGHT ERROR RETURNED IN     CIPHER.190
        C     TZ FROM SYZYGY.                                                       CIPHER.191
   240        IF(T.LT.ROOTT(FP,PS,N2)) Y=-Y                                         CIPHER.192
   251        GO TO 800                                                             CIPHER.193
   252  500   CONTINUE                                                              CIPHER.194
   252        NFLAG=1                                                               CIPHER.195
   253        GO TO 800                                                             CIPHER.196
   254  520   CONTINUE                                                              CIPHER.197
   254        NFLAG=1                                                               CIPHER.198
   255        IF(THETA.GT.2.617) GO TO 800                                          CIPHER.199
   261        NFLAG=0                                                               CIPHER.200
   261        IF(THETA.LT.0.3) GO TO 530                                            CIPHER.201
   263        THES=VNORM*(1.+.5/RR**3)*SIN(THETA/2.)/RR*DTEL                        CIPHER.202
   274        THD=THETA-THES                                                        CIPHER.203
   276        IF(THD.LT.0.01) GO TO 530                                             CIPHER.204
   304        X=RR*SIN(THD)                                                         CIPHER.205
   312        GO TO 600                                                             CIPHER.206
   312  530   CONTINUE                                                              CIPHER.207
        C                                                                           CIPHER.208
        C     POINT LIES ON EXTREMELY SMALL STREAM FUNCTION AND IS CLOSE            CIPHER.209
        C     TO RISE AXIS-- APPROXIMATE X COORDINATE,CALCULATE Y FROM X.           CIPHER.210
        C                                                                           CIPHER.211
   312        X=RH*1.01                                                             CIPHER.212
   314        GO TO 600                                                             CIPHER.213
   314  540   CONTINUE                                                              CIPHER.214
   314        GO TO 800                                                             CIPHER.215
   315  560   CONTINUE                                                              CIPHER.216
   315        TDIF=TZ-TLAST-T                                                       CIPHER.217
   320        X=SQRT(P)*RLAS3                                                       CIPHER.218
   326        YRL=ABS(RL2-X*X)                                                      CIPHER.219
   331        Y=-SQRT(YRL)                                                          CIPHER.220
   337        IF(T.LT.ROOTT(FP,PS,N2)) Y=-Y                                         CIPHER.221
   350        Y=Y+VNORM*TDIF                                                        CIPHER.222
   353        GO TO 800                                                             CIPHER.223
```

```
CIPHER
      353   600    CONTINUE                                          CIPHER.224
      354          X2=X*X                                            CIPHER.225
      355          DNOM=ABS(X2-2.*P)+.000001                         CIPHER.226
      361          Y=ABS((X2/DNOM)**.66666-X2)                       CIPHER.227
      365          Y=-SQRT(Y)                                        CIPHER.228
      373          IF(T.LT.ROOTT(FP,PS,N2)) Y=-Y                     CIPHER.229
      404   800    CONTINUE                                          CIPHER.230
      404          RETURN                                            CIPHER.231
      405          END                                               CIPHER.232
```

```
SUBPROGRAM LENGTH
01634
```

```
SCHCK
                SUBROUTINE SCHCK(XOU,K,ALPHA,XSAV)                                SCHCK.2
          C                                                                       SCHCK.3
          C     THIS SUBROUTINE CALCULATES THE SHOCK DISPLACEMENT                 SCHCK.4
          C     OF POINT XOU FROM EVENT K,GIVING THE NEW POSITION XSAV.           SCHCK.5
          C                                                                       SCHCK.6
          C         INPUTS                                                        SCHCK.7
          C     XOU =INITIAL POSITION                                             SCHCK.8
          C     K=EVENT NUMBER                                                    SCHCK.9
          C     ALPHA=SHOCK SCALING PARAMETER                                     SCHCK.10
          C                                                                       SCHCK.11
          C         OUTPUT                                                        SCHCK.12
          C                                                                       SCHCK.13
          C     XSAV=FINAL POSITION AFTER DISPLACEMENT.                           SCHCK.14
          C                                                                       SCHCK.15
          C         TIME DEPENDENT MODEL PARAMETERS                               GEOTD.2
                COMMON /GEOTD/ NF, INDXF(50), RTF(50), RLF(50), HF(50), GCF(50),  GEOTD.3
               1            GLF(50), HMAXF(50), HMINF(50), KINDF(50), TILTF(50),GEOTD.4
               2            AGE(50), NOTA, INDXD(100), DLABL(100), WDR(100),    GEOTD.5
               3            HDR(100), RTBS(100), RLBS(100), HBS(100), HNBS(100),GEOTD.6
               4            GCBTA(100),GLBTA(100),TF(50),TCHAR(50),MAGIC(50),   GEOTD.7
               5             XFR(50),YFR(50),ZFR(50),RUT(50)                    GEOTD.8
                COMMON/RADDAT/XIN(3,10),XEV(3,10),REIN(10),REV(10),VXYZ(3,10),    RADDAT.2
               1    VRZ(10),CVEC(3,10)                                            RADDAT.3
          C                                                                       RADDAT.4
          C         EVENTX PARAMETERS                                             EVENTX.2
                COMMON /EVENTX/ NX, IDX, TB(50), HB(50), GCB(50), GLB(50),        EVENTX.3
               1              IDGAD(50), RHOB(50), HSB(50), TEMB(50), VRISE(50),EVENTX.4
               2              RDZERO(50), HHZERO(50), RUZERO(50), BXB(50),      EVENTX.5
               3              BYB(50), BZB(50), LHVB(50),XALPHA(50), KALCH      EVENTX.6
          C                                                                       SCHCK.19
          C     FINAL POSITION OF EVENT K,  FIRST FIND DISTANCE BETWEEN           SCHCK.20
          C     EVENT AND POINT..                                                 SCHCK.21
          C                                                                       SCHCK.22
                DIMENSION XOU(3),XSAV(3),C(3),D(3)                                SCHCK.23
                CALL SUBVEC(XOU,XIN(1,K),C)                                       SCHCK.25
     11         SR=XMAG(C)                                                        SCHCK.26
     17         SRLAM=SR/ALPHA                                                    SCHCK.27
     20         DLAM=0.096/(SRLAM*(2.+SRLAM))                                     SCHCK.28
     23         SRNEW=SR-DLAM*ALPHA                                               SCHCK.29
     25         CALL UNITV(C,D)                                                   SCHCK.30
     27         C(1)=SRNEW*D(1)                                                   SCHCK.31
     31         C(2)=SRNEW*D(2)                                                   SCHCK.32
     32         C(3)=SRNEW*D(3)                                                   SCHCK.33
     34         AB=1                                                              SCHCK.34
     36         CALL VECLIN(AB,XIN(1,K),AB,C,XSAV)                                SCHCK.35
     46         RETURN                                                            SCHCK.37
     47         END                                                               SCHCK.38

SUBPROGRAM LENGTH

00101

FUNCTION ASSIGNMENTS
```

ROOTT

```
                 FUNCTION ROOTT(FP,PS,N2)                                       ROOTT.2
            C                                                                   ROOTT.3
            C    THIS FUNCTION SUBPROGRAM CALCULATES THE TIME CONTOUR THAT      ROOTT.4
            C    CROSSES ZERO AT A GIVEN STREAM FUNCTION VALUE                  ROOTT.5
            C                                                                   ROOTT.6
            C    INPUT                                                          ROOTT.7
            C    INPUT DEFINED IN CIPHER                                        ROOTT.8
            C                                                                   ROOTT.9
            C    OUTPUT                                                         ROOTT.10
            C    ROOTT=TIME OF CONTOUR CROSSING ZERO AXIS FOR GIVEN X           ROOTT.11
            C                                                                   ROOTT.12
                 DIMENSION PS(15),TCRS(15)                                      ROOTT.14
                 DATA TCRS/4.396,3.31,2.77,1.71,1.09,.989,.809,.569,.4118,.303, ROOTT.15
               1    .223,.1227,.068,.0158,.00013/                               ROOTT.16
                 A1=FP                                                          ROOTT.17
      6          A2=1.-FP                                                       ROOTT.18
     10          YC=TCRS(N2)**A2*TCRS(N2-1)**A1                                 ROOTT.19
     17          ROOTT=YC                                                       ROOTT.20
     21          RETURN                                                         ROOTT.23
     21          END                                                            ROOTT.24
```

SUBPROGRAM LENGTH

00056

DISCAP

```
              SUBROUTINE DISCAP(P,Q,D,H,S1,DIST,SR21)
       C
       C      THIS ROUTINE FINDS THE CLOSEST DISTANCE TO THE LINE OF CENTERS
       C      OF INITIAL EVENT POSITION AND FINAL EVENT POSITION,
       C      USES VECTOR ANALYSIS AND ROSCOE LIBRARY.
       C
              DIMENSION P(3),Q(3),C(3),F(3),R(3),H(3)
              DIMENSION D(3)
              AP=1
   12         CALL SUBVEC(Q,P,C)
   15         CALL SUBVEC(D,P,F)
   23         CALL PROJ(F,C,G)
   26         CALL SUBVEC(G,F,R)
   31         DIST=XMAG(R)
   42         CALL VECLIN(AP,D,AP,R,H)
   46         SR21=XMAG(C)
   50         S1=XMAG(G)
       C
       C      DETERMINE THE SENSE OF G WITH RESPECT TO C
       C
   62         AM=DOT(C,G)
   64         S1=SIGN(S1,AM)
   73         RETURN
   73         END
```

SUBPROGRAM LENGTH

00125

EVENAD

```
                  SUBROUTINE EVENAD(SPUU,NAI,PXYZ,XOU)
            C
            C         THIS SUBPROGRAM DOES THE VECTOR ADDITION OF THE POSITION PXYZ
            C     TO GIVE A FINAL DISPLACEMENT
            C
            C         INPUTS
            C
            C     SPOU(3,L)=POSITION ARRAY OF POINT AFTER AFFECT FROM EVENT L
            C     NAI=NUMBER VECTORS
            C
            C         OUTPUT
            C
            C     XOU(3)=FINAL VECTOR POSITION
            C
                  DIMENSION SPOU(3,NAI),PXYZ(3),XOU(3),C(3)
                  CALL XMIT(-3,0.0,C)
      10          NM1=NAI-1
      14          DO 100 L=1,NM1
      16          LL=L+1
      17          A=1
      21          B=1
      23          CALL VECSUM(A,SPOU(1,L),B,SPOU(1,LL),C)
      37    100   CONTINUE
      41          BSUB=-1.*FLOAT(NM1)
      43          CALL VECLIN(A,C,BSUB,PXYZ,XOU)
      47          RETURN
      50          END
```

SUBPROGRAM LENGTH

00077

SECTION VI

TYPICAL OUTPUT

Three test problems were run to give some typical output from the flow field models. Each test problem consisted of finding a position at burst times of a given particle at the calculation times. The first two problems consisted of a single event at 43 km and a spherical Vortex radius of 8.68 km. The last test problem consisted of a five burst scenario at relatively small yields and altitudes.

The output gives the number of actual events that have occurred as distinguished from hydromerged events. The values of the parameters are given for both the initial and the calculation time. The initial parameters are labeled with the "Type" - INITIAL; the calculation time parameters have a "Type" - ACTUAL. The height, colatitude and longitude are given along with the indexes of the fireballs affecting the point. The position of the point at the burst time is then given.

For example, the first test problem has a point at 48 km at 2.7 sec; at 0.0 sec the point is at 41 km. The drastic change is altitude for such a short time span is a result in assuming that the shock arrives instantaneously at burst time. A correction of this error has been made and will appear in the next version. The shock error is even more apparent for the given point at 70 km at 2.78 sec which was at 53 km at 0.0 sec.

```
OUTPUT FOR FLOW FIELD TEST -- PROBLEM NUMBER=     1

                         NUMBER OF ACTUAL EVENTS =  1
                         COORDINATES AT BURST TIME FOR     1 EVENTS
EVENT NO.    TIME   HEIGHT(KM)   COLATITUDE  LONGITUDE   RADIUS(KM)  VELOCITY(KM/S) TYPE
      1      0.00     43.0000      41.2988   238.9807      8.68003      0.0000000INITIAL


     COORDINATES OF    1 EVENTS AT CALCULATION TIME =      2.780
EVENT NO.    TIME   HEIGHT(KM)   COLATITUDE  LONGITUDE   RADIUS(KM)  VELOCITY(KM/S) TYPE
      1      2.78     43.1565      41.2988   238.9807      6.34633       .0562837 ACTUAL

                         POSITION OF POINT AT CALCULATION TIME =     2.78SEC

                            HEIGHT(KM)   COLATITUDE   LONGITUDE
                              45.0000      41.2449    238.9807

     POINT APPEARS INSIDE BURST NUMBER     1


                            HEIGHT(KM)   COLATITUDE   LONGITUDE
                              51.0000      41.2449    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE      1
     POSITIONS OF POINT AT EVENT TIMES

EVENT   TIME   HEIGHT(KM)   COLATITUDE   LONGITUDE
    1   0.00     44.3049      41.2895    238.98070

                            HEIGHT(KM)   COLATITUDE   LONGITUDE
                              48.0000      41.2449    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE      1
     POSITIONS OF POINT AT EVENT TIMES

EVENT   TIME   HEIGHT(KM)   COLATITUDE   LONGITUDE
    1   0.00     41.3261      41.2960    238.98070

                            HEIGHT(KM)   COLATITUDE   LONGITUDE
                              44.0000      41.2449    238.9807

     POINT APPEARS INSIDE BURST NUMBER     1


                            HEIGHT(KM)   COLATITUDE   LONGITUDE
                              70.0000      41.2449    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE      0
     POSITIONS OF POINT AT EVENT TIMES

EVENT   TIME   HEIGHT(KM)   COLATITUDE   LONGITUDE
    1   0.00     53.3256      41.2781    238.98070
```

```
           COORDINATES OF   1 EVENTS AT CALCULATION TIME =     25.000
EVENT NO.   TIME   HEIGHT(KM)  COLATITUDE  LONGITUDE  RADIUS(KM) VELOCITY(KM/S) TYPE
        1  25.00     56.9528      41.2988   238.9807     11.89217        .5581114 ACTUAL

                      POSITION OF POINT AT CALCULATION TIME =   25.00SEC

                         HEIGHT(KM)  COLATITUDE   LONGITUDE
                          45.0000     41.2449     238.9807

NUMBER OF EVENTS AFFECTING POINT =   1 INDEXES ARE      1
          POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00    44.2030     41.2489    238.98070

                         HEIGHT(KM)  COLATITUDE   LONGITUDE
                          51.0000     41.2449     238.9807

          POINT APPEARS INSIDE BURST NUMBER     1

                         HEIGHT(KM)  COLATITUDE   LONGITUDE
                          48.0000     41.2449     238.9807

          POINT APPEARS INSIDE BURST NUMBER     1

                         HEIGHT(KM)  COLATITUDE   LONGITUDE
                          44.0000     41.2449     238.9807

NUMBER OF EVENTS AFFECTING POINT =   1 INDEXES ARE      1
          POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00    43.3918     41.2460    238.98070

                         HEIGHT(KM)  COLATITUDE   LONGITUDE
                          70.0000     41.2449     238.9807

NUMBER OF EVENTS AFFECTING POINT =   1 INDEXES ARE      1
          POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00    42.7415     41.2993    238.98070
```

```
         COORDINATES OF    1 EVENTS AT CALCULATION TIME =     50.000
EVENT NO.    TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE  RADIUS(KM) VELOCITY(KM/S) TYPE
       1  50.00     71.5777      41.2988   238.9807     17.34179        .5715537 ACTUAL

                   POSITION OF POINT AT CALCULATION TIME =   50.00SEC

                     HEIGHT(KM)  COLATITUDE   LONGITUDE
                      45.0000     41.2449    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE      1
         POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00     44.7787     41.2428    238.98070

                     HEIGHT(KM)  COLATITUDE   LONGITUDE
                      51.0000     41.2449    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE      1
         POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00     48.8496     41.2555    238.98070

                     HEIGHT(KM)  COLATITUDE   LONGITUDE
                      48.0000     41.2449    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE      1
         POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00     46.8892     41.2483    238.98070

                     HEIGHT(KM)  COLATITUDE   LONGITUDE
                      44.0000     41.2449    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE      1
         POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00     44.1808     41.2419    238.98070

                     HEIGHT(KM)  COLATITUDE   LONGITUDE
                      70.0000     41.2449    238.9807

         POINT APPEARS INSIDE BURST NUMBER     1
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                  COORDINATES OF    1 EVENTS AT CALCULATION TIME =      75.000
EVENT NO.    TIME   HEIGHT(KM)   COLATITUDE  LONGITUDE  RADIUS(KM) VELOCITY(KM/S) TYPE
       1  75.00      83.6563       41.2988   238.9807    22.69456         .5420841 ACTUAL

                        POSITION OF POINT AT CALCULATION TIME =    75.00SEC

                           HEIGHT(KM)  COLATITUDE   LONGITUDE
                            45.0000     41.2449     238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE      1
           POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00     44.5750     41.2413    238.98070

                           HEIGHT(KM)  COLATITUDE   LONGITUDE
                            51.0000     41.2449     238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE      1
           POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00     49.4407     41.2511    238.98070

                           HEIGHT(KM)  COLATITUDE   LONGITUDE
                            48.0000     41.2449     238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE      1
           POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00     47.0339     41.2453    238.98070

                           HEIGHT(KM)  COLATITUDE   LONGITUDE
                            44.0000     41.2449     238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE      1
           POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00     44.0560     41.2410    238.98070

                           HEIGHT(KM)  COLATITUDE   LONGITUDE
                            70.0000     41.2449     238.9807

           POINT APPEARS INSIDE BURST NUMBER     1
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OUTPUT FOR FLOW FIELD TEST -- PROBLEM NUMBER=    2

                  NUMBER OF ACTUAL EVENTS =  1
                  COORDINATES AT BURST TIME FOR     1 EVENTS
EVENT NO.   TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE  RADIUS(KM) VELOCITY(KM/S) TYPE
       1   0.00    43.0000     41.2988   238.9807     8.68003      0.0000000INITIAL


       COORDINATES OF   1 EVENTS AT CALCULATION TIME =    25.000
EVENT NO.   TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE  RADIUS(KM) VELOCITY(KM/S) TYPE
       1  25.00    56.9528     41.2988   238.9807    11.89217       .5581114 ACTUAL

                  POSITION OF POINT AT CALCULATION TIME =   25.00SEC

                    HEIGHT(KM)  COLATITUDE   LONGITUDE
                     43.0000     41.2988    238.9807

NUMBER OF EVENTS AFFECTING POINT =   1 INDEXES ARE     1
       POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00    38.3511     41.2987    238.98096

                    HEIGHT(KM)  COLATITUDE   LONGITUDE
                     41.0000     41.2444    238.9807

NUMBER OF EVENTS AFFECTING POINT =   1 INDEXES ARE     1
       POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00    40.4063     41.2390    238.98070

                    HEIGHT(KM)  COLATITUDE   LONGITUDE
                     39.0000     41.2444    238.9807

NUMBER OF EVENTS AFFECTING POINT =   1 INDEXES ARE     1
       POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00    38.6152     41.2371    238.98070

                    HEIGHT(KM)  COLATITUDE   LONGITUDE
                     35.0000     41.2444    238.9807

NUMBER OF EVENTS AFFECTING POINT =   1 INDEXES ARE     1
       POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00    35.0228     41.2381    238.98070

                    HEIGHT(KM)  COLATITUDE   LONGITUDE
                     25.0000     41.2444    238.9807

NUMBER OF EVENTS AFFECTING POINT =   1 INDEXES ARE     0
       POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00    25.2218     41.2450    238.98070
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          COORDINATES OF    1 EVENTS AT CALCULATION TIME =     50.000
EVENT NO.    TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE  RADIUS(KM) VELOCITY(KM/S) TYPE
       1  50.00      71.5777      41.2988   238.9807    17.34179        .5715537 ACTUAL

                    POSITION OF POINT AT CALCULATION TIME =   50.00SEC

                        HEIGHT(KM)  COLATITUDE   LONGITUDE
                          43.0000     41.2988    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE      1
          POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00     38.3162     41.2987    238.98094

                        HEIGHT(KM)  COLATITUDE   LONGITUDE
                          41.0000     41.2444    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE      1
          POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00     40.6565     41.2366    238.98070

                        HEIGHT(KM)  COLATITUDE   LONGITUDE
                          39.0000     41.2444    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE      1
          POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00     38.5610     41.2355    238.98070

                        HEIGHT(KM)  COLATITUDE   LONGITUDE
                          35.0000     41.2444    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE      1
          POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00     34.7834     41.2375    238.98070

                        HEIGHT(KM)  COLATITUDE   LONGITUDE
                          25.0000     41.2444    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE      0
          POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00     25.2218     41.2450    238.98070
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           COORDINATES OF    1 EVENTS AT CALCULATION TIME =     75.000
EVENT NO.    TIME  HEIGHT(KM)   COLATITUDE  LONGITUDE  RADIUS(KM) VELOCITY(KM/S) TYPE
        1  75.00      83.6563      41.2988   238.9807     22.69456        .5420841 ACTUAL

                          POSITION OF POINT AT CALCULATION TIME =     75.00SEC

                             HEIGHT(KM)  COLATITUDE   LONGITUDE
                              43.0000      41.2988    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE       1
          POSITIONS OF POINT AT EVENT TIMES

EVENT   TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1   0.00     38.3387     41.2987    238.98095

                             HEIGHT(KM)  COLATITUDE   LONGITUDE
                              41.0000      41.2444    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE       1
          POSITIONS OF POINT AT EVENT TIMES

EVENT   TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1   0.00     40.1993     41.2370    238.98070

                             HEIGHT(KM)  COLATITUDE   LONGITUDE
                              39.0000      41.2444    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE       1
          POSITIONS OF POINT AT EVENT TIMES

EVENT   TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1   0.00     38.2960     41.2358    238.98070

                             HEIGHT(KM)  COLATITUDE   LONGITUDE
                              35.0000      41.2444    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE       1
          POSITIONS OF POINT AT EVENT TIMES

EVENT   TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1   0.00     34.4239     41.2379    238.98070

                             HEIGHT(KM)  COLATITUDE   LONGITUDE
                              25.0000      41.2444    238.9807

NUMBER OF EVENTS AFFECTING POINT =    1 INDEXES ARE       0
          POSITIONS OF POINT AT EVENT TIMES

EVENT   TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1   0.00     25.2218     41.2450    238.98070
```

OUTPUT FOR FLOW FIELD TEST -- PROBLEM NUMBER= 3

NUMBER OF ACTUAL EVENTS = 5
COORDINATES AT BURST TIME FOR 5 EVENTS

EVENT NO.	TIME	HEIGHT(KM)	COLATITUDE	LONGITUDE	RADIUS(KM)	VELOCITY(KM/S) TYPE
1	0.00	5.0000	41.2988	239.0093	.26705	0.0000000INITIAL
2	0.00	9.1500	41.2988	238.9807	.26705	0.0000000INITIAL
3	.20	9.5000	41.2988	238.9807	.26705	0.0000000INITIAL
4	12.00	12.0000	41.2988	239.0093	.26705	0.0000000INITIAL
5	20.00	11.5000	41.2988	239.0093	.26705	0.0000000INITIAL

COORDINATES OF 5 EVENTS AT CALCULATION TIME = 22.000

EVENT NO.	TIME	HEIGHT(KM)	COLATITUDE	LONGITUDE	RADIUS(KM)	VELOCITY(KM/S)	TYPE
1	22.00	5.9868	41.2986	239.0093	.55334	.0448540	ACTUAL
2	22.00	10.2207	41.2988	238.9807	.52425	.0486689	ACTUAL
3	22.00	10.6602	41.2988	238.9806	.53710	.0532197	ACTUAL
4	22.00	12.7610	41.2988	239.0093	.56068	.0761038	ACTUAL
5	22.00	11.5083	41.2988	239.0093	.80005	.0041602	ACTUAL

POSITION OF POINT AT CALCULATION TIME = 22.00SEC

HEIGHT(KM)	COLATITUDE	LONGITUDE
9.0000	41.2988	238.9864

NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 2
POSITIONS OF POINT AT EVENT TIMES

EVENT	TIME	HEIGHT(KM)	COLATITUDE	LONGITUDE
1	0.00	8.9472	41.2988	238.98617
2	0.00	8.9509	41.2988	238.98615
3	.20	8.9539	41.2988	238.98650
4	12.00	8.9343	41.2988	238.98650
5	20.00	8.9745	41.2988	238.98679

HEIGHT(KM)	COLATITUDE	LONGITUDE
9.1500	41.2988	238.9864

NUMBER OF EVENTS AFFECTING POINT = 2 INDEXES ARE 2 3
POSITIONS OF POINT AT EVENT TIMES

EVENT	TIME	HEIGHT(KM)	COLATITUDE	LONGITUDE
1	0.00	9.0902	41.2988	238.98613
2	0.00	9.0938	41.2986	238.98611
3	.20	9.0276	41.2988	238.98677
4	12.00	9.0163	41.2988	238.98656
5	20.00	9.0570	41.2988	238.98682

HEIGHT(KM)	COLATITUDE	LONGITUDE
9.9000	41.2988	238.9864

NUMBER OF EVENTS AFFECTING POINT = 2 INDEXES ARE 2 3
POSITIONS OF POINT AT EVENT TIMES

EVENT	TIME	HEIGHT(KM)	COLATITUDE	LONGITUDE
1	0.00	9.9259	41.2988	238.98459
2	0.00	9.9289	41.2988	238.98457
3	.20	9.8821	41.2988	238.98479
4	12.00	9.9681	41.2988	238.98715
5	20.00	9.8951	41.2988	238.98776

HEIGHT(KM) COLATITUDE LONGITUDE
10.8000 41.2988 238.9864

POINT APPEARS INSIDE BURST NUMBER 3

HEIGHT(KM) COLATITUDE LONGITUDE
11.2000 41.2988 238.9864

NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 3
POSITIONS OF POINT AT EVENT TIMES

EVENT	TIME	HEIGHT(KM)	COLATITUDE	LONGITUDE
1	0.00	10.9589	41.2988	238.98487
2	0.00	10.9615	41.2988	238.98486
3	.20	10.9726	41.2988	238.98489
4	12.00	11.0468	41.2988	238.98545
5	20.00	11.1508	41.2988	238.98800

COORDINATES OF 5 EVENTS AT CALCULATION TIME = 30.000

EVENT NO.	TIME	HEIGHT(KM)	COLATITUDE	LONGITUDE	RADIUS(KM)	VELOCITY(KM/S)	TYPE
1	30.00	6.3005	41.2988	239.0093	.66313	.0433504	ACTUAL
2	30.00	10.5424	41.2988	238.9804	.63083	.0464166	ACTUAL
3	30.00	10.9904	41.2988	238.9803	.64461	.0500237	ACTUAL
4	30.00	13.3330	41.2988	239.0093	.67395	.0740575	ACTUAL
5	30.00	12.2492	41.2988	239.0093	1.06126	.0749170	ACTUAL

POSITION OF POINT AT CALCULATION TIME = 30.00SEC

HEIGHT(KM) COLATITUDE LONGITUDE
9.0000 41.2988 238.9864

NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 2
POSITIONS OF POINT AT EVENT TIMES

EVENT	TIME	HEIGHT(KM)	COLATITUDE	LONGITUDE
1	0.00	8.9360	41.2988	238.98620
2	0.00	8.9398	41.2988	238.98617
3	.20	8.9427	41.2988	238.98652
4	12.00	8.9237	41.2988	238.98653
5	20.00	8.9614	41.2988	238.98681

HEIGHT(KM) COLATITUDE LONGITUDE
9.1500 41.2988 238.9864

NUMBER OF EVENTS AFFECTING POINT = 2 INDEXES ARE 2 3
POSITIONS OF POINT AT EVENT TIMES

EVENT	TIME	HEIGHT(KM)	COLATITUDE	LONGITUDE
1	0.00	9.0802	41.2988	238.98616
2	0.00	9.0838	41.2988	238.98614
3	.20	9.0038	41.2988	238.98682
4	12.00	8.9956	41.2988	238.98662
5	20.00	9.0348	41.2988	238.98687

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                         HEIGHT(KM)  COLATITUDE   LONGITUDE
                            9.9000     41.2988    238.9864

NUMBER OF EVENTS AFFECTING POINT =   2 INDEXES ARE      2    3
        POSITIONS OF POINT AT EVENT TIMES

EVENT  TIME  HEIGHT(KM)  COLATITUDE  LONGITUDE
    1  0.00     10.0422     41.2988    238.98593
    2  0.00     10.0452     41.2988    238.98592
    3   .20     10.0131     41.2988    238.98637
    4 12.00     10.0539     41.2988    238.98801
    5 20.00     10.0126     41.2988    238.98916

                         HEIGHT(KM)  COLATITUDE   LONGITUDE
                           10.8000     41.2988    238.9864

          POINT APPEARS INSIDE BURST NUMBER    2

          POINT APPEARS INSIDE BURST NUMBER    3

                         HEIGHT(KM)  COLATITUDE   LONGITUDE
                           11.2000     41.2988    238.9864

          POINT APPEARS INSIDE BURST NUMBER    3
```

COORDINATES OF 6 EVENTS AT CALCULATION TIME = 40.000

EVENT NO.	TIME	HEIGHT(KM)	CCLATITUDE	LONGITUDE	RADIUS(KM)	VELOCITY(KM/S)	TYPE
1	40.00	6.6980	41.2988	239.0093	.78772	.0424488	ACTUAL
2	40.00	10.9361	41.2988	238.9804	.75159	.0446572	ACTUAL
3	40.00	11.3972	41.2988	238.9802	.76687	.0476776	ACTUAL
4	40.00	13.8771	41.2988	239.0093	.83183	.0670375	MERGED
5	40.00	13.1745	41.2988	239.0093	1.38873	.0837271	MERGED
6	40.00	12.7447	41.2988	239.0093	.10076	0.0000000	MERGED

POSITION OF POINT AT CALCULATION TIME = 40.00SEC

HEIGHT(KM)	COLATITUDE	LONGITUDE
9.0000	41.2988	238.9864

NUMBER OF EVENTS AFFECTING POINT = 1 INDEXES ARE 2

POSITIONS OF POINT AT EVENT TIMES

EVENT	TIME	HEIGHT(KM)	COLATITUDE	LONGITUDE
1	0.00	8.9217	41.2988	238.98621
2	0.00	8.9255	41.2988	238.98618
3	.20	8.9264	41.2988	238.98652
4	40.00	8.9083	41.2988	238.98654
5	40.00	8.9446	41.2988	238.98681

HEIGHT(KM)	COLATITUDE	LONGITUDE
9.1500	41.2988	238.9864

NUMBER OF EVENTS AFFECTING POINT = 2 INDEXES ARE 2 3

POSITIONS OF POINT AT EVENT TIMES

EVENT	TIME	HEIGHT(KM)	COLATITUDE	LONGITUDE
1	0.00	9.0677	41.2988	238.98617
2	0.00	9.0714	41.2988	238.98615
3	.20	8.9734	41.2988	238.98684
4	40.00	8.9634	41.2988	238.98663
5	40.00	8.9999	41.2988	238.98688

HEIGHT(KM)	COLATITUDE	LONGITUDE
9.9000	41.2988	238.9864

NUMBER OF EVENTS AFFECTING POINT = 2 INDEXES ARE 2 3

POSITIONS OF POINT AT EVENT TIMES

EVENT	TIME	HEIGHT(KM)	COLATITUDE	LONGITUDE
1	0.00	9.8363	41.2988	238.98655
2	0.00	9.8394	41.2988	238.98654
3	.20	9.8084	41.2988	238.98696
4	40.00	9.7927	41.2988	238.98927
5	40.00	9.7619	41.2988	238.98903

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